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do not repair

REINFORCED CONCRETE BRICK PLANT

BY

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ARMOUR INSTITUTE OF TECHNOLOGY

1913

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AT 302
Kornfield, L. P.
The design of a reinforced
concrete brick plant

THE DESIGN
OF A
REINFORCED CONCRETE BRICK PLANT
CAPACITY 60,000 to 80,000 BRICK DAILY.

A THESIS

PRESENTED BY

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AND

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TO THE

PRESIDENT AND THE FACULTY MEMBERS

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HISTORICAL.

The earliest examples of this branch of the ceramic art were doubtless the sun-dried bricks of Egypt, Assyria and Babylonia. Remarkable to say, many of these, which in a northern climate the frosts of a single winter would destroy, have been preserved for 3000 years or more by the dry warm atmosphere of those countries. Sun-baked bricks of ancient date are also found in the mud walls of old towns in India. Kiln-baked bricks must have been the products of a later time. They are found in all the chief ruins of ancient Babylonia, where they were often used to face or bind together walls of sun-dried bricks and occasionally they were even ornamented with enameled colors. These ancient bricks, whether baked by the sun or by fire, were all made of clay mixed with grass or straw. The ancient Greeks, probably owing to the abundance of stone in their possession, cared little for building with burned clay; but most of the great ruins in Rome were originally built of brick, and the Romans appear to have introduced the art into England. Interesting historical informa-

has been obtained from impressions on Roman and especially on Babylonian bricks. In many instances the Roman bricks found in England have been removed from their original position and employed in the construction of buildings of later date. In 1260 the first modern or Flemish brick were made in England at Little Wenham Hall in Suffolk. In America bricks were made in Virginia as early as 1612, in New England in 1647, in Philadelphia in 1685 and later in the west as civilization moved westward.

VARIETIES OF BRICK.

Common building brick may be made of any clay that can be molded well and then burned to a hard, uniform texture and red color. Good bricks do not absorb more than 10% water. Brick are classed as arch-red or salmon, according to whether they come from the center, inner or outer portions of the kiln. The first are inclined to be hard or brittle and the last to be too soft.

Front brick, also known as pressed, re-pressed, Philadelphia pressed or face brick is a smooth, sharp-edged brick, first class in color and is used for the front or any other exposed surface of buildings where good effect is particularly desired. Then there are many other varieties of brick, such as fire brick, enameled or glazed brick, paving brick and sewer brick.

There are approximately 100 varieties of brick manufactured in the United States. A conservative estimate of the brick produced in the United States would be about 50,000,000,000 annually. The United States claims to have some 18,000 brick manufacturers.

TECHNOLOGY OF CLAY.

DEFINITION:- The term "Clay" in its most common usage includes a large variety of substances, which, when mixed with water, are said to become plastic, or capable of being molded. The numerous different varieties of clay differ widely in both composition and physical characteristics, but the examinations of many clays show the universal presence of certain constituents which compose the clay base. This clay base is called kaolin. It is owing to this mineral that clay possesses the property of plasticity which makes it of use to man. Clay may then be defined as a mineral mixture in which kaolinite is present in sufficient amount to impart to the mass its characteristics to a degree allowing of its use in the manufacture of clay wares. Kaolin beds or deposits are found in Eastern United States, West Cripple Creek Region of Colorado, Mexico, England, Etc.

The physical properties of raw clay are structure, color, feel, slaking, strength, bonding power, plasticity, shrinkage, porosity, specific gravity and fineness of grain, and the physical pro-

perties of burnt clay are structure, color, strength, shrinkage, porosity, specific gravity and fusibility.

STRUCTURE:- The structure of a deposit of clay is of importance since on it depends the means employed in removing the clay from the bank and in prepairing it for the molding process. Clay structures are slaty, shaly, jointed, laminated or concretionary when viewed in the pit.

COLOR:- The colors which clays assume are almost infinitely variable. Common clays are colored brown, red, black, blue, gray, buff and all tints between.

FEEL:- The feel test is one of the first to which the prospector resorts in ascertaining the texture and plasticity of a clay.

SLAKING:- A substance slakes when by the addition of water it is broken into small particles and crumbles down. The importance of this property is that a clay which takes water eagerly and rapidly crumbles down will work up into the plastic, mddable condition with great readiness than one that requires pulverizing before water has any appreciable influence upon it.

STRENGTH:- The cohesion of clays may be tested from two standpoints, that of tension and compression or resistance to crushing.

BONDING POWER:- Bonding power of clays is defined as the ability to stand the addition of non-plastic matter. The clays standing the addition of the largest amount of sand or other inert substance and whose strength is least impaired by such addition is said to possess the greatest bonding power.

PLASTICITY:- Were it not for the property which clays possess of becoming plastic when moistened with water, their economic importance would be almost entirely lost. Plasticity is thus the characteristic of clays, when wet, which allows of their being molded into the innumerable shapes and sizes of modern clay wares.

SHRINKAGE:- It is well known that clays on drying undergo a decrease in all their dimensions. This decrease is due to the settling together of the clay particles when the water is evaporated.

POROSITY:- Porosity of a clay may be defined as the ratio between the volume of the clay and the open or pore space amonn the clay particles. This is a very important physical factor in burnt clay wares.

SPECIFIC GRAVITY:- Specific Gravity has not been shown to be a factor of especial importance in the economic treatment of clays. According to the conception that specific gravity is a function of porosity, it is considered to have a bearing on the fusibility of clays.

FINENESS OF GRAIN:- The fineness of the grain of clays has an important bearing on plasticity, shrinkage, porosity and rapidity with which they can be dried and burned and their fusibility.

FUSIBILITY:- A substance is said to be fusible when by subjection to a certain set of conditions, it may be made to change from the solid to liquid state.

PROCESSES IN THE MANUFACTURE OF CLAY WARES.

WINNING OF RAW MATERIAL.

In the manufacture of any products making use of raw materials found in nature, the first problem to be met is that of winning. Winning includes that preliminary part of the process of manufacture which brings the crude materials to the prepairing machinery. It is always advantageous to build the manufacturing plant as close as possible to the deposit of raw material.

The common means by which clays are won are surface digging, quarrying and mining.

SURFACE DIGGING:- Clays of the more earthy, loose-textured varieties occuring at the surface of the ground may be dug in shallow pits. Surface digging is carried out by the use of the shovel and wheelbarrow. A second method is by the plow and scraper. The use of the steam shovel for open-surface workings is prevalent in some of the larger clay working centers of the country.

QUARRYING:- Quarry methods are resorted to in digging clays where the latter are of such a character or the strata of such a thickness as to require more forcible means in loosening them up than the pick, shovel and plow. The shales which furnish a large

proportion of the raw material utilized in the clay industry where unweathered, are usually more or less indurated. This induration has often proceeded to such an extent that the deposit takes on a slaty or stony hardness and can be broken only by drilling and blasting.

MINING:- The third method of winning clay is only employed where the clay to be won is of such a nature as to be especially desirable for some line of manufacture and where clay which will serve the same purpose is not obtainable at the surface. Mining is practiced in the clay industry only to a limited extent. It is more expensive than any other method of clay getting because of the extra equipment necessary in the way of timber and extensive track lines and provisions for ventilation, light, etc.

Following the winning of the clay or its removal from the bank, the different stages of the process of manufacture are as follows:- Transportation to works, preparation for molding, formation of the ware, drying and burning. These different operations vary in importance with the process of manufacture and the character of the clay used.

TRANSPORTATION OF THE RAW MATERIAL TO THE WORKS.

This is accomplished in several ways, depending upon the amount of clay required and the location of the plant with respect to the clay deposit. Where the slope is low and the distance short the clay may be wheeled from the pit in barrows. Large quantities of clay can be economically removed and carried some distance in scrapers. In some instances clays are shipped in by rail from distant points. Horse and cart haulage is quite common. Transportation over car lines is practiced in nearly all the larger plants.

A more common location of the plant, however, is above the level of the base of the clay deposit. In this case the cars are drawn up an inclined trestle or tramway using steam or horse power. Steam power transmitted from the power plant of the factory secondarily by means of cables is the common agent. The cars are drawn up by the cable which winds around a drum located at the works end of the line. The drum is usually actuated by a small auxiliary engine supplied with steam from the main boilers. If considerable power is necessary and the capacity

of the plant fairly large, it is usually advisable to install a small engine of the required horse power to do the work. Clays are hoisted in this manner regardless if the slope be long and low or short and high.

The cars used in this connection are of three principal types, viz., side, bottom and end dump. Any of these may be had of varying capacity carrying from one up to two or three cubic yards of clay. Whether one style or another is used depends on the arrangements for dumping; and, if a large or a small car, on the amount of clay required and the height to which it is to be raised. For a plant of an average capacity, say 60,000 brick per day, from 75 to 85 cubic yards of clay will be needed. With cars each carrying a yard and a half of clay; to supply this output it would take forty to forty five cars per day. Instead of merely meeting the demand for clay as it is needed at the prepairing machinery, provision is usually made for a reserve supply. Sometimes sheds or large storage bins are provided where the clay is stored and drawn upon when needed. The storage bin

is always located so as to bring the clay as near as possible to the machinery in order to reduce the expense of extra handling to the minimum. The common plan is to elevate the car track somewhat above the level of the grinding apparatus and dump the raw clay on a platform or into the bin so that it may be fed, largely by gravity, to the machine. An excellent arrangement is a funnel shaped bin opening below directly into the dry pan and surrounding it by a substantial platform. At the mouth of the funnel a rotating cylinder having usually four compartments may be placed having a very slow speed and feeding the same quantity continuously and at a uniform rate into the dry pans. In a device of this type two different clays or shales or combinations of both may be fed into the pans by having the rotating cylinder divided by a partition in the center of the drum and having two funnel openings instead of one with two compartments in the bins. In most modern car systems means are furnished for automatically dumping the clay when the cars reach a certain point in their course.

PREPARATION OF THE RAW MATERIAL.

The condition of the clay as it comes from the pit is not ordinarily such that it can at once be formed into ware. If it is a hard shale clay, it will require grinding and a thorough mixing with water. If a surface clay, grinding is less important but complete mixing is necessary. Clay banks seldom consist of material constant in character from top to bottom. By grinding and mixing an average of the bank is accomplished. In order to attain a uniform composition, which is always desirable, it is not only essential that the different kinds of clay be added in certain proportions but that the mixture be uniform in all parts of the same piece of ware. This reduction of the raw materials to a degree of fineness, which experience has shown best for the class of goods to which they are applied, and blending or mixing these constituents into a homogeneous body is accomplished by two typical methods, the dry and the wet.

DRY METHODS OF PREPARATION.

CRUSHERS:- The first step in the preparation of clay in the dry way is the reduction to fine size. For this purpose the common rock crusher may be used. The machine consists of two jaws, one of which is stationary and the other mounted to work on a pivot. A modification of this machine, although based upon the same principle, is the cylindrical hopper in the center of which is supported a gyratory cone-shaped metal head with a corrugated surface. It requires little power to operate these machines. The capacity of these crushing devices will vary from two to two hundred tons per hour, depending upon the material. In the clay industries crushers are available for breaking dry and the most brittle material only. The property which clay possesses of packing, and thus apt to clog, when subjected to pressure, although it may apparently be perfectly dry, renders any machine which communicates by crushing inapplicable except to a very limited extent in clay manufacture.

ROLLS:- Crushing rolls are used to a considerable extent in the clay industry as a means of preliminary

preparation of both dry and wet clay. Typically they consist of two revolving rolls between which the clay passes. In installing a machine of this sort an accurate knowledge of the character of the clay to be fed to it would be necessary in order to select a machine that would give the highest possible efficiency. A set of average sized rolls will prepare clay for 25,000 to 150,000 brick (95 to 570 tons of clay) per day, depending on the speed at which it is run.

DISINTEGRATORS:- Where variation in construction are brought in so that the machine becomes more than a mere crushing device the term"Disintegrator" is applied. Among disintegrators, two broad divisions may be made, those that pulverize partly by crushing and in part by rubbing and those in which comminution is accomplished by the force of impact. Disintegrators are employed most advantageously with dry clays and in the dry clay processes of manufacture but are also recommended for plastic materials. Their capacities vary with the clay and with the speed of revolution. They are made with capacities

of from 60 to 400 tons of clay per day and require from 10 to 40 horse power.

DRY PANS:- The dry pan crusher is employed to a greater extent than any other grinding machine for shale and other hard and lumpy clays. It has a wide range of usefulness because of its ability to pulverize any hard material, from worn-out fire bricks for use as grog, and hard limestone in the cement industry,to the less refractory classes of raw clays. The machine consists essentially of a revolving metal pan above which are supported two large mullers which, in different sized pans, range in weight from two to three tons. The inner portion of the pan floor, upon which the mullers rest, is solid. The outer portion has a perforated bottom and the clay passing beneath the rollers is carried outward over the screen plates by the centrifugal force of revolution. The mesh varies with the clay and with the degree of fineness desired, but the majority of pans are made with three thirty-seconds or one eigth inch perforations. All material failing to pass this mesh is gathered in by scrapers set so

as to throw it again immediately in front of the revolving mullers. The ground clay passing the screen plates is caught on a receptacle beneath the pan and concentrated at the foot of an elevator which conveys it to the screens.

Dry pans are constructed with either wood or steel frames. Whatever the material of the supporting framework, it must be substantial and built to withstand constant jar and heavy jolting. The elasticity that a wood frame possesses means the consumption of more power in operating than a perfectly rigid frame.

Dry pans are made from five to nine feet in diameter with mullers having eight to fourteen inch face. The power required to drive one of these pans depends upon the materials to be ground and the degree of fineness. So far as economy is concerned, they are wasteful, but no other machine has been found that will replace the dry pan with an equal expenditure of power. Likewise, its capacity is variable. With an average dry clay it may be said that a nine foot pan will pulverize to pass a one-eight mesh screen over one hundred tons per day of ten hours.

SCREENS:- There are few, if any, of the different machines for grinding dry clays that reduce them to particles of such a uniform size that a later grading process is not required. Grading is accomplished by means of screens. Screens are made with meshes depending principally upon the size of particles to pass them, although, as will be seen later, it depends partly upon the style of screen employed. There are two classes of materials used in the manufacture of clay screens, wire netting and perforated metal. The former is much used, but less and less as the merits of the latter become known. The proportion of open space to solid metal in the perforated screen as now made, approximates that of the wire screen, which gives it an equal screening power. The perforated screen being entirely in one piece is smooth and there is not the chance for roots or other fibrous matter to lodge in the meshes as is the case in the wire screen. It is thus easier to clean and to keep clean. The loosening of a single wire is apt to disable the wire screen while the metal is not subject to this disadvantage.

There are three chief types of screens, viz., the inclined stationary screen, the inclined vibrating screen and the rotary screen.

INCLINED STATIONARY SCREENS:- The inclined screen is essentially a rectangular trough, the bottom being covered with netting or perforated metal. Its length varies from ten to fourteen feet. The trough is inclined at an angle of thirty to forty five degrees according to the size of particles that are to pass the mesh of the screen and the condition of the clay. It should be so supported that the inclination may be adjusted. The clay is brought up by an elevator from the grinding apparatus and dumped onto the upper end of the screen. Its fall over the screen is due to gravity alone and at a certain inclination will have a definite velocity. Clay passing through the screen, falls to a trough below and is conveyed to a bin best located immediately above the tempering machine.

INCLINED VIBRATING SCREEN:- The inclined shaking screen is similar to the fixed screen except that is is much shorter and is set at such a low angle of inclination that mechanical aid is used to cause a continual downward movement of the stream of clay: Figuring alone on the basis of the amount of clay

screened, the vibrating screen gives a much higher efficiency.

ROTARY SCREENS:- There are two principal types of rotating screens, cylindrical and polygonal. The rotary screen consists of an open framework covered or lined with screen material, either wire cloth or perforated steel plate. These screens give more trouble in keeping them clean than the other two described.

Ground clay storage bins are usually provided for the reception of the ground clay. In a bin of considerable size, several cubic yards may be stored for use when the preparing machinery is not in operation. A convenient shape for the storage bin is that of a large hopper, broad above with a long taper to a relatively small opening in the center of the bottom. The bin should be as high as feasible and its sides as steep as feasible since there is always the tendency of pulverized clay to pack and to bank up under the most favorable conditions. For this reason if the clays are conveyed from the bin to the pug mill or auger machine by a spout, the

latter will furnish a more constant supply of clay and cause less trouble if it is large and uniform in size or even broader than is the opening from the bottom of the bin.

THE FORMATION OF CLAY WARES.

Manufacture of Brick.

There are two methods of brick making, namely, soft and stiff mud. The soft mud process will not be considered.

STIFF MUD:- The term "Stiff Mud" signifies the distinction between this and the other processes of making brick. The clay is tempered to a stiffly plastic state so that it can be molded, but it will not shape or flow under slight pressure as does the clay when prepared by the soft mud process. The clay is made of such a consistency that it will, under heavy pressure, flow through a die in the shape of a bar, the latter being strong enough to retain its form even when subjected to considerable strain either longitudinally or laterally.

There are two principal types of stiff mud machines, the upright and the horizontal. Both consist essentially of a small pugging chamber at the exit of which is the die that forms the bar of clay. On the same shaft with the pugging knives is an auger which is the means of forcing the clay through the die. The clay ordinarily comes to the brick machine from

some preparing device in which it has been tempered and rendered thoroughly plastic. In the brick machine the pugging arms carry the clay to the auger and the latter compresses it into the die. Through the action of the pugging knives and auger under heavy pressure the clay is strongly compacted and issues from the machine in a solid bar.

The bar of clay runs from the machine onto a moving belt which carries it to the cutting table. The brick may be made "end"or "side" cut, according as the width of the bar of clay is the width or length of a brick.

The maximum capacity of the stiff mud machines making side cut brick is eight to fifteem thousand per hour requiring seventy to seventy-five horse power. Auger machines of smaller size are on the market with capacities ranging from two thousand upwards brick per hour.

CUTTING TABLES:- There are several types of cutting tables. The cutting device may be either by hand or automatic. The cutting is done by wires which are tightly drawn from projecting parts of a metal frame.

This frame may be parallel to the moving bar of clay and consist of strips between which any number of wires, up to a dozen are drawn the desired thickness of the bricks apart. By variations in construction this type of cutter may cut the clay by direct lateral movement of the wires, or by a lateral, partially rotary-downward motion.

The requirements which a brick cutter must fulfil are several. The wires must make a smooth and square cut brick. The movement of the cutter should be so connected with the movement of the clay that a varying velocity of the latter will communicate a similar change in the movement of the cutting wires.

After the brick are cut they pass from the cutting table to an off-bearing belt. The latter having a velocity greater than that of the moving bar separates the brick as they leave the cutter convenient distances for handling to the dryer cars.

Of the other methods of brick making there are: The repressing of brick made by stiff mud process also soft mud process to some extent, dry press which is

manufacture of brick from dry or partially dry clay, manufacture of drain tile, hollow brick or blocks, sewer pipe and pottery.

Properties of Clay.

The requirements which a clay must meet to be applicable for stiff mud manufacture are somewhat closely drawn. Many of the clays suitable for soft mud brick are equally well adapted for stiff mud methods. Stiff mud must possess a high degree of plasticity in order to give satisfaction in the auger machine. Since they are more plastic, shrinkage in drying is usually great and they must be strong to resist drying strains.

Drying of Clay Wares.

The drying is primarily a process of water evaporation. Evaporation of the water must be carried on under such conditions, however, as not to injure the ware dried.

The water which clays contain consists of water of plasticity or tempering water and hygroscopic water. The latter is always present in all pulverized or earthy substances which are allowed to

stand in contact with the atmosphere. The amount of hygroscopic moisture in clays depends partially on the humidity of the air, but more largely on the fineness of the grain of the clays. Only water of plasticity is, therefore, ordinarily expelled in drying. Popping of brick frequently results from too rapid or overheating of clay in drying due to the steam which cannot escape as rapidly as it is formed and thus exerts accumulative pressure.

The conditions in closed chamber dryers are different from the old out door air method. The air no longer circulates of itself but a draft must be produced to move it. The heat for drying is not contained in the air as it enters from the outside, but must be supplied to it artificially. In this system the brick enter the dryer at atmospheric temperatures and leave it at much higher temperatures.

Practical Considerations in drying Clays.

If the drying of clays were alone a matter of water evaporation heat and air supply could be so proportioned as to accomplish this with the smallest waste. Since, however, the preservation of the form

and strength of the ware itself is the primary consideration, drying must be so conducted as to most economically remove the water while retaining these necessary characteristics of the ware dried.

The operation of removing water from clay ware, commonly regarded as a continuous process, may fairly be divided into three more or less well defined stages. These are: heating, up stage, period of shrinking, stage of evaporation or completion of the drying proper.

In the continuous dryer, which is most used at the present time, it has been found most practical as well as economical to allow the ware to stand in a steamy atmosphere until thoroughly heated before drying is permitted to begin. At the completion of drying the clay is said to be "bone" or "white" dry and is ready for the kiln although it still contains sometimes as high as 3% of water.

There are five typical methods of accomplishing the drying of clays, namely, outside air drying, the hot floor, sewer pipe or slatted floor, periodic or chamber dryer and the continuous tunnel dryer. Of these the fifth process will be considered.

Continuous Tunnel Dryer.

This dryer is usually built on the tunnel plan the details of which are shown on sheets numbers five and six. The air inlet is a series of openings from a large sewer or duct running the whole width of the tunnels. These openings are controlled by dampers and are so proportioned that their total area will not exceed 50% of cross section of the main air duct.

The principal variations among dryers of this type are found in the methods of heating the air which does the drying. In general, these may be classified under two heads, direct and indirect.

(By fuel burned for the purpose.
Direct(
(By waste gases from other processes.

(Radiation from heated brick work.
Indirect(
(Radiation from steam heated surfaces.

Drying by Waste Gases from Kilns.

In this process positive control is necessary. This is accomplished by use of fans. The use of fans for controlling the draft has the advantage over natural draft in that it is a positive force, moving

exactly equal volumes of air during similar periods of time, and while the temperature and humidity may vary from day to day the speed of the fan may be adjusted so as to pass the requisite amount of air under different conditions.

In this system the heated gases from the cooling kiln are drawn into the dryer. Great care is taken, however, to turn the gases into the stack before they have cooled down to their dew point.

BURNING OF CLAY WARES.

Combustion of Fuel.

The burning of clay wares is accomplished by the consumption of fuel. Under practical firing conditions, it is well known that it is impossible to burn fuel without bringing into the furnace much larger quantities of air than are necessary for perfect combustion. Where it is neither desirable nor necessary to have a large excess of air passing through the fire, the incidental losses in the flue gases may be held much lower by careful methods of firing. The work of the mechanical stoker is to facilitate combustion by so distributing and proportioning fuel and air that complete oxidation is accomplished with the minimum amount of air.

PRACTICAL CONSIDERATIONS:- The typical methods of burning solid fuels are three, viz., flat grate bar furnace, inclined grate bar furnace and dead bottom fire. The flat grate bar is by far the commonest in the clay industry. The grate is placed in a horizontal position and the air for combustion comes from below through the bars and the layer of fuel. With great care this grate can be made to yield the highest possible heat efficiency.

The inclined grate furnace differs from the last in having the grate bars set on a slope downwards from the opening into the furnace.

Dead bottom firing is done without the use of grate bars. The furnace is constructed with a front ash pit opening for draft and one from above for the admission of fuel changes which occur in the burning of clays.

The changes which take place in clays during burning may be classed under two heads, chemical and physical. The physical character of clay is altered through chemical processes. The chemical changes that clays undergo are essentially the same for all clays. These changes are sufficiently distinct that the whole burning process may be divided into three stages, namely:- dehydration, oxidation and vitrification.

Dehydration is a term which expresses the process of driving from the clay all the water it contains. It occurs at temperatures below a bright red heat and is practically completed at 700 degrees centrigrade.

After successful expulsion of the water is accomplished no further change takes place until low red heat is attained and the temperature can be rapidly raised to this point. Here the combined water commences to leave. This is the "Water-smoking" period of dehydration and is completed with an increase of 150 degrees of temperature. The water-smoking period is best conducted with plenty of air to dilute the fire gases and remove the water and other vapors that begin to leave the clay. The ideal fuel for this period is one free from sulphur and water.

In the second stage of oxidation, the prevailing changes that occur are processes of combination with oxygen. This latter reaction gives to common clays their red color and is the most important phenomenon occuring during this period. The process of oxidation begins about 500 to 600 degrees centrigrade and should be completed within 900 degrees.

Types of Kilns.

There are various types of kilns in the brick industry. Of the numerous kilns in common use, prac-

tically all may be included in the two groups, intermittent and continuous. The intermittent kiln embraces by far the largest number of clay burning kilns in all sections of the country. The intermittent kilns may be divided as follows:- Under intermittent there are the updraft and the downdraft; subdivisions under updraft are temporary and permanent, under temporary there are the English Clamp and the American Scove; under permanent there are the direct, Semi Muffle and Muffle; under direct the rectangular and round under the semi muffle and muffle the pottery kilns. The subdivisions under downdraft are the direct and muffle; under direct the round and rectangular, under the round the single stack and the multiple stack and under the rectangular the single stack and the multiple stack.

The temporary up-draft kiln is exemplified by the Old English Clamp and the American Scove kilns. In both these types the kiln is built chiefly of the ware to be burned.

The permanent up draft kilns are separated into direct and muffle, according to whether the combustion

gases pass through the ware, thus heating by convection, or are separated from the ware by a partial or complete enclosing wall, through which the clay is burned by radiation and conduction.

The round updraft kiln is the early pottery kiln, and its use has continued up to the present time.

Down Draft Kilns.

Round Down Draft Kilns:- The commonest example of the down-draft kiln is the round, single stack kiln. Modifications of the simple type are many, according to the conditions and clay in different places. The number of stacks is found to vary largely and the arrangement of the flues leading to the stacks and the openings from the kiln chamber into the flues are points of variable design.

The burning of all wares through which it is allowable for the fire gases to circulate is accomplished by the transfer of heat from the fire by these moving currents. The production of an equal draft through all portions of a kiln of ware is thus an all-important consideration.

The round down-draft kiln was first built with but one center draft opening which led to an outside stack. The evolution of this type of kiln has taken place largely by modifications and improvements in the flue systems. An early step in this evolution was to have in place of the center well-hole one open flue across the middle of the kiln bottom. The gases are naturally drawn by the shortest route to the exit. A further modification was to afford a flue circling the interior of the kiln and connecting with a diametric flue such as was first used alone. To prevent extreme concentration of the draft in this kiln the flues are closed for some distance in the part of the kiln nearest the stack. While of course such a provision serves to retard the more pronounced flow, the tendency for the gases to leave the kiln as near the stack as possible is always present and invariably disturbs the equality of the draft.

To equalize the draft from circumference to center the use of radial flues outward from the center is the most common method of construction. Occasional

openings are made into these flues. The openings are larger the farther they are from the center so that the outside portions will draw as strongly as the central portions. A perfect draft in an empty kiln may be very far from such when the kiln is full of brick.

The permanent false floor is a part of nearly all recent down-draft kilns. It is built of fire brick and so supported with open brickwork as to leave ample space below it in which the gases may circulate freely to the flues. The shallower the flues are and still furnish the required cross section the more favorable will they be for the freedom of draft. The upward movement of the gases in the stack has alone to do with producing the draft. The closer the stack is to the kiln, the greater the extent to which this lateral draft difficulty is avoided.

Beside the proper construction of the various parts of the kiln so that the operation may be under accurate control, there must be provided means for this control. The flow of the draft is controlled

by dampers. These are of two chief types, slide and valve dampers. The former are more common than the latter. Slide dampers may be operated either horizontaly or vertically. When in horizontal position they are in the stack and when vertical they usually are at the base of the stack in the main flue. These are generally made of heavy sheet iron. An improvement over sheet iron is the fire clay damper. The horizontal damper is a more perfect contrivance as it tends by its own weight to prevent leakage of the flue gases around it.

The number of stacks on round kilns varies from one to as many as there are fire holes. Aside from the control the cost of construction is greater for numerous small chimneys than for one large one to do the same work.

For burning brick which are of necessity closely set and thus tend to restrict the draft, kiln diameters range from 20 to 30 feet and even more. The height of the kiln should be made to exceed very little the height of the ware stacked in it. Brick are s from 25 to 35 courses high. Six feet is an average

distance from the floor to the spring of the arch. The arch should have about a 4 ft. rise. The fire holes are best set from 2 to 3 ft. below the level of the kiln floor. By so doing the radiation from the base of the bag walls becomes effective, heating the ware near the kiln floor. The number of fire holes range from 8 to 12 according to the diameter of the kiln. The type of fire place depends on the ware to be burned. The stack is placed close to the kiln and the flue connections should be as shallow as possible.

The round down draft kilns hold from 30,000 to 60,000 brick. An average rectangular kiln contains 150,000 to 200,000 brick.

DESIGN.

In designing a plant, after a company has been organized and the capacity determined, the first step is to make a survey of the ground and determine the general topography. Having made the survey the drainage system may be laid out and the various grades determined. Then the general plan of works is made from which the remainder of the design is worked.

Sheet #1 shows the general plan of works. Sheet #2 shows the elevations and depths of all footings, foundations, piers and flues.

The clay after leaving the pit is hauled up an inclined trestle to the concrete clay storage bin. This is shown on sheet #1. Sheet #7 shows a detail of the reinforced concrete raw material storage bin.

The material after being dumped into the bin may be passed through crushers or pulverizers if necessary. If not necessary, it passes directly into the nine foot dry pans where it is prepared for the pug mill. Sheets number land 3 show this. After being ground in the dry pan the clay falls through a screen down into a pit and from this pit it is elevated by means of a belt with buckets attached to the elevator tower and discharged onto a screen. The screen passes through a certain amount and the remainder is returned by means of the tailings spout to the dry pans where it is reworked. Sheet #3 shows a detail of this method.

After the clay has passed through the mesh of the screen it is fed into a small ground clay bin large enough to hold a one day run. From here it is fed onto a belt conveyor by means of the opening in the bottom of hopper bin, thence to the pug mill already described. The details of this are shown on sheets numbers 1 and 3. After being mixed thoroughly and made plastic in the pug mill it is fed into the brick machine, which is of the auger type. In the brick machine the clay is compressed in a long column and issues out of the brick machine die onto the cutting table. On the cutting table the brick is cut into the desired length automatically and then passes on to the off-bearing belt. From the off-bearing belt the green brick are loaded on the dryer car, the capacity of which is about 600 to 800 brick. The brick which are imperfect are dumped off the end of the off-bearing belt and elevated up by means of elevator buckets to a return conveyor which returns the clay back into the pug mill to be used over again. After being loaded on the dryer cars, the cars are placed in the dryer tunnels, where they are left for about

thirty six hours and then removed to the kilns. The kilns are of the round down draft type with two stacks and ten fire boxes. After the kiln is burned which takes from 48 to 96 hours, it is left to cool. Then a "gooseneck" is fitted into one of the sealed door ways of the kiln and the waste heat gases are drawn out into the underground flues shown on sheet number 4. The gases are drawn out by means of a 12 foot induction fan making about 120 revolutions per minute. The gases after passing through the flues are drawn up into the suction chamber and then discharged through the fan into the main duct and then through the openings into the dryer tunnels shown on sheets number 5 and 6. A 16 ft. exhaust fan is so located that it draws the heat through the tunnels at the required velocity. This exhaust fan makes 130 R.P.M. Both the induction and exhaust fans are steel plate, three quarter housing.

After the brick are burned they are removed from the kilns and placed in the storage shed, the details of which are shown on sheet #8. From this

storage shed the brick are shipped by rail to various points as desired.

DRYER TUNNELS:- If slabs and girders be reinforced to take care of the negative bending moments over the supports they will act as continuous beams, and the bending moment at the center of the span will be reduced. It is considered good practice to use the following values:- For beams and slabs continuous over both supports let $M - 1/12\ wl^2$, continuous over one support only let $M - 1/10\ wl^2$ and freely supported let $M - 1/8\ wl^2$; where M - bending moment at the center of the span in foot pounds, w - total uniform live and dead load in pounds per square foot and l - length of span in feet. When moments are used in equations they are to be multiplied by 12 to reduce the moment to inch pounds. Unless care be taken to insure proper position of the steel over the supports it is well to use $M - 1/10\ wl^2$.

For the shear let V - total shear at the section in pounds, let b - width of the section in inches, let d - depth of the section to center of steel in inches and let small v - the unit shear in pounds per

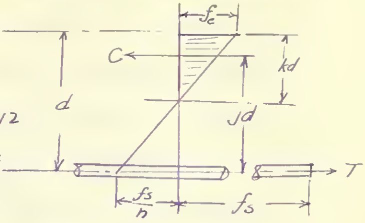
square inch. Therefore $v - V/bd$. When the beam is reinforced the working stresses may be assumed at 100 to 125 pounds per square inch.

Let the stress on the concrete f_c be assumed as 600# per square inch and the stress on the steel f_s as 15,000# per square inch, the weight of the concrete as 150# per cubic feet. Then assume the live load as 40# per square foot. Using the maximum span of 13 feet for roof of dryer and a width of 12 ft. which will answer for all the sections at either the loading or unloading end of sheds.

It is often very desirable to reinforce the slabs in two directions and support the slab by means of beams on four sides. If the panel is square then one half of the total load is carried in each direction, but as panels have a greater length than breadth the distribution of load is determined by the formula $r = l^4 / l^4 + b^4$ in which r equals the proportion of the load carried by the reinforcement placed the short way of the slab, l = length and b = breadth of the slab. The ratio of length to breadth = $13/12 = 1.083$. By plotting values of r and values

of 1/b we get a curve such that the vertical ordinates give the proportion of the total load carried by the short reinforcement.

$E_s/E_c = n = 15$. Steel ratio - $A/bd = p$.
$k = \sqrt{2pn + pn^2} - pn$ und $j = 1 - 1/3\,k$.
Resisting Moment of Steel $M_s = f_s p j b d^2$
and resisting moment of concrete M_c
$= \frac{1}{2} f_c k j b d^2$ but $A = pbd$; therefore
$M_s = f_s A j d$ and $M_c = \frac{1}{2} f_c k b d^2$.



Assume a 4" slab the weight of which is 40 + 48 or 88# per sq. ft. Consider 60/100 of the total load carried by the shorter span or 52.8# per sq. ft. Consider 40/100 of the total load carried by the longer span or 35.2# per sq. ft. The bending moment for the short span, B.M. is 1/10 X load X span X span or B.M. is 1/10 X 52.8 X 12 X 12 or 760.3 ft. pounds or 9025 inch pounds. For a slab of 4" the depth to the steel is 3 inches. From "Turneaure & Mauer" page 297, the permissable B.M. is 10600 "#. $M_c = 1/6\ f_c\ bd^2$ therefore $d^2 = 6M_c/bf_c$ or 6 X 9025/600 X 12 or 7.52 or d = 2.7" which is approximately 3". $M_s = 15000 \times A \times \frac{7}{8}d$ therefore A = 8 X 9025/15000 x 7 X 3 = 0.229 sq. in. per foot width of slab steel required. From Turneaure & Mauer page 292 use round rods $\frac{3}{8}$" diameter spaced $5\frac{1}{2}$" on centers. Area of same is 0.24. B.M. for long span = 1/10 X 35.2 X 13x13 X 12 or 7140"#. A = 8 X 7140/15000 X 7 X 2.375 - 0.221 therefore use $\frac{3}{8}$"

diameter rods spaced $5\frac{1}{2}$" on centers. The shear at the end of the slab is 344/3x12 or 9.6# and 35.2 x 12/36 = 11.7# shear. Therefore we see that the shear at the end of the slab is very small compared to other quantities and will be amply taken care of. The interior slabs of the roof, for a 4" slab, the bending moment $M = 1/12\ wl^2$ and as the slab is continuous over the supports will be less than when $M = 1/10\ wl^2$ and therefore the previous calculations and amount of reinforcing will take care of all conditions.

Beams or girders to carry the roof load to the column may be used but in this case a shallow beam will be considered. For a simple beam M max = wl^3. We will only consider the maximum conditions. The bending moment $M = 1.20 \times 88.5 \times \overline{13}^2 = 18000$"#. Assume 6" I Beams @ 12.25#. Carnegie safe load in pounds for 13 foot span = 5960#. $M = SI/c$, $S = Mc/I$, $M = \frac{1}{8}\ wl^2$; therefore $M = \frac{1}{8} \times 12.25 \times \overline{13}^2 \times 12 = 21130$"# and $S = 21130 \times 3 / 218 = 2940$#, therefore use 6" I Beam @ 12.25# throughout both loading and unloading shed roofs. Where 6" I Beam rests on columns it may be advisable to rivet a $\frac{3}{8}$" plate on I beam in order

to distribute the roof load uniformly over the entire cross section of column. The maximum load on the column will be approximately 14,000#. As long as the steel and concrete adhere the relative intensities of stress in the two materials will be as their moduli of elasticity. Let A denote total cross section of column - A_c cross section of concrete - A_s cross section of steel - p the ratio of steel area to total area = A_s/A - f_c = stress on concrete - n the ratio of moduli of steel and concrete at the given stress - $f_c = E_s/E_c$ - P = total strength of plain column for stress f_c and P_1 - total strength of reinforced column for stress f_c; then $P = f_c A$ and $P' = f_c A_c + f_s A_s = f_c (A - pA) + f_c npA \therefore P' = f_c A [1 + (n-1)p]$ #1; also $P'/P = 1 + (n-1)p$ #2. The relative increase in strength caused by reinforcement is $\frac{P'-P}{P} = (n-1)p$ #3.

Let n = 15, assume 2% of steel then A = 14000/ 600 x 1.28 = 18.6 therefore use 6" x 6" square column. Using 36 sq. in. and load to be carried as 14000#, the safe strength of a plain concrete column would be 600 x 36 = 21600#. Then from above equation P_1/P = 14/21.6 = 1 + (15 - 1) P, therefore use 4$\frac{3}{4}$" round rods. Assume bearing pressure of soil at 4000 to 8000# per square foot. Then area required would be 2.3 sq. ft. - use footing 18" square.

Design of tunnel roof the span of which is 3'9" let $M = 1/10\ wl^2$ for end spans and $1/12\ wl^2$ for intermediate. Assume a 4" slab weight of which is 48# and let the live load be 40# per sq. ft. $M = 1/10 \times 88 \times \overline{3.9}^2 = 134$ ft. # $= 1610$"#, $M = 1/12 \times 88 \times \overline{3.9}^2 \times 12 = 1340$"#. $M_s = 15000 \times A \times \frac{7}{8}d$. $A = 8 \times 1610 / 15000 \times 7 \times 3 = .041 \square''$. Therefore use $\frac{1}{4}$" rods, spaced 12" on centers, area $= .05 \square''$.

The walls of the dryer tunnels are to be 4" thick with $\frac{1}{4}$" round rods spaced 24" on centers longitudinally and horizontally.

Span of vent duct slab = 5.5 feet. Now let $M = 1/10\ wl^2 = 1/10 \times 200 \times \overline{5.5}^2 \times 12 = 7260$" pounds. $M_s = 15000 \times A \times \frac{7}{8}d$, therefore $A = 8 \times 7260/15000 \times 7 \times 6 = .09 \square''$, use $\frac{3}{8}$" round rods spaced 8" on centers. A dryer car and load of brick weigh about 4000#, and as only two wheels can be on vent duct slab at one time or 2000# per rail, the total load will be 200# per sq. ft. including the weight of the 6" slab. Although this calculation shows more reinforcing than necessary it is advisable to use it due to the uncertainty of the live load.

The weight of roof trusses or purlins for uniform loadings was determined as follows:- $W = PL/300 + 6L + PD/3$ in which W = weight of truss per sq. ft. of bldg., L = span of truss in feet, D = distance center to center of trusses in feet, P = load per sq. ft. on truss. Weight of purlins $W_1 = P_1D/45 - \frac{1}{4}$ in which W_1 = weight of purlins per sq. ft. of bldg., D = distance center to center of trusses in feet and P_1 = load per sq. ft. on purlins.

RETAINING WALL:- Required a wall to form the sides of a clay storage bin 18 ft. high and surcharged at a slope $\theta = \phi$, the angle of repose, ϕ being 35 degrees and the weight of the clay or shale 100# per cu. ft. $\cos\phi = 0.81915$, $x = 18$ ft. Then $Py = (100 \times 18\ ) \div 2 \times 0.81915 = 13300$ lbs. & $P = Py \cos\theta = 13300 \times .81915 = 10900$ lbs. ϕ = true angle of repose of the material behind the wall. Py = thrust from the material behind the wall in a direction parallel to the surface of the bank, the horizontal component of the resultant of which acts at a height of $x/3$ above the base. Let x = height of the wall HK and w = weight of a unit of volume (1 cu. ft.) of the material behind the wall then

$$Py = \frac{wx^2}{2}\cos\theta\,\frac{\cos\theta - \sqrt{\cos^2\theta - \cos^2\phi}}{\cos\theta + \sqrt{\cos^2\theta - \cos^2\phi}}.$$

If the surface slopes at the angle of repose, that is if the angle of surcharge is the angle of natural slope $\theta = \phi$ and Py = $x^2w/2$ cos ϕ. If the surface was horizontal θ = zero then Py = $(x^2 w/2)\left(\frac{1-\sin\phi}{1+\sin\phi}\right)$.

Graphically draw the vertical HK shown on sheet number 7, through the inner edge of the heel and from H draw HM making an angle of 35 degrees with the horizontal. Bisect the angle KHM by the line HN and draw the slope line KN parallel to HM. Make HP = x/3 = 6 feet, and draw PS parallel to HN which will pass through the centers of gravity of the triangles HKL, KLN & HKN

Area of KLN = 9.33 x 10.33 ÷ 2 = 48.2, area of HKL = 9.33 x 18.00 ÷ 2 = 84, and area of HKN = 48.2 + 84 = 132.2. As a check on the work lay off He = 12 = 2x/3 and draw the horizontal cutting PS at b. Lay off eh = 1/3 Ke and draw hk horizontal cutting PS produced at k. Then will b be the center of gravity of the triangle HKL and K will be the center of gravity of the triangle KLN. Scaled distance bk = 10.62 ft. Then 10.62 x 48.2 ÷ 132.2 = 3.87 feet. Lay off bd = 3.87 feet and d will be the center of gravity of the triangle.

The area HKN multiplied by 100 will be the weight of prism one foot long = 132.2 x 100 = 13220#. With the decimal scale of forces make RT vertical equal to 13220 and draw TS parallel to KN cutting RS at S. TS will then represent by the scale of forces the amount and direction of the resultant Py, the center of action of which is through R. Drop a vertical S, cutting the horizontal through R at S;' then RS' will be the resultant horizontal component of Py and scales 10750.

Assume the foundation 3.5 feet below the ground line which is far enough below for protection, under ordinary conditions, from frost upheaval and try a base 2 feet thick. The top of the base will then be at EH' or 1.5 feet below the floor and ground level at H and the lever arm of the resultant, horizontal component will be RH' = 7.5 feet. The bending moment of the wall ABCD at CD will be 10750 x 7.5 = 80625 foot pounds. For a span of 10 feet the load per lineal foot for 1" of width that will give a moment of 80625 ft. #. will be w = 8x80625/100 x 12 = 537#. Therefore a depth h of 24" is required. Make DC = 24" and AB = 6" and AD vertical. Try a base 11 ft. long with its center in

plane of the vertical face of the wall AD. Then b = 11 feet, ED = 5.5 feet and CH' = 3.5 feet and GH' will be 2'. Assume weight of concrete as 140# per cu. ft., calculated the weight and center of gravity of the wall, base and filling over the heel as follows:- CIKH' = 19.167 x 3.5 x 100 = 6680 x 1.75 = 11720, BCI = 19.167 x 1.5 ÷ 2 x 100 = 1430 x 4.0 = 5720, BCm = 19.167 x 1.5 ÷ 2 x 140 = 2010 x 4.5 = 9060, ABmD = 19.167 x 0.5 x 140 = 1340 x 5.25 = 7020 and EFGH = 2.33 x 11 x 140 = 3590 x 5.5 = 19780. Therefore 15050 x 3.9 = 53300. Lay off BY = 3.9 feet and from Y lay off YV = 15050#. Lay off VO equal and parallel to ER than YO will be the resultant on the foundation and its amount can be found by scaling or by equation. $YO = \sqrt{15050^2 + 10750^2} = 18500$. The resultant will intersect the base at q where Cq = 3.90 + (9.5 + 10750/10750) = 3.9 + 6.60 = 10.5 and Dq = 10.5 - 5.5 = 5 ft. Then p = 15050/11 = 1370 -, p' = 1370- (15050 x 5 ÷ 20.17) = 5230 +, and p" = 1370 - (15050 x 5 ÷ 20.17) = -2490, from which it is seen that while intensity of the uplift at the extreme end of the heel is less than 1.5 tons per square foot, the maximum intensity of pressure at

the outer end of the toe is less than three tons per sq. ft. which is well within the allowable pressure on any satisfactory foundation. The wall will therefore be safe from overturning, and while the value of P' would be somewhat increased if there were nothing to resist the uplift p", the frictional resistance of the material filled in behind the wall will be sufficient to balance the uplift when the latter is small. In this case the total uplift will be (11 x 2490 ÷ 7720) x 2490 ÷ 2 = 4400#, while a friction of 20% of Py = 2650. This however is not depended upon to insure stability and is not in this case, since without any resistance to the uplift p' would be 15050 ÷ (11 - 10.3) x 3/2 = 6000# or about 3 tons per sq. ft. The resultant of the reaction on the toe would be [(1370 x 5.5 x 2.75) + (3860 x 5.5 x 3.67 ÷ 2)] ÷ [(1370 x 5.5) + (3860 x 2.75)] = 3.3 ft. in front of plane AD and its amount is 14800#. The moment on the toe will then be 14800 x 3.3 = 48800 '#. If there was no resistance to the negative reaction, it would be nearly 15050 x 3.67 = 55000'#. Using the larger value w = (8 x 55000/100 x 12) = 360# per lineal foot and by table of safe loads per lineal foot for beams 1"

thick, 22" is depth of beam required. The shear on the plane CD is equal to P = 10750# which is 10750/28 x 12 = 31# per sq. in. or only about one third of the safe shearing strength. Where the vertical rods enter the base the anchorage required, must equal the maximum stress in the rods 80625 x 12/18.45 = 52000#. If the base is 24" thick the surface of the rods embedded in the base per lineal foot of wall will be approximately 300", the perimeter of the rods being 10.6 inches using 1¼" round rods, 4" center to center (Page 292 Turneaure & Mauer). The shear per sq. in. of surface will be 52000/300 = 173# per sq. in. As the longitudinal shear exceeds the limit of the safe working value of adhesion, the rods should be deformed or some mechanical bond used. While the moment on the heel in this case is much less than on the toe, for practical purposes, it will generally be preferable to make the base of uniform thickness throughout. The reinforcement in the base will consist of 1¼" rods, 2½" above the bottom and below the top, spaced 4" on centers in the bottom and 8" centers on the top and all running transversely. The weight of the wall itself will add to the compression per sq. in. on the concrete at D, caused by

the bending moment, an amount proportional to its height. In this case it will be near enough to take this at 18 x 140/144 = 18# per sq. in. which may be neglected. If the wall was very high and extreme accuracy desired this compressive stress due to the weight of the wall would be considered.

COUNTERFORTS:- Let P = 10750# and assuming counterforts spaced 10 ft. apart on centers, the thrust on each counterfort will be 107500# and the bending moment at CD will be 10750 x 7.16 = 770,000'#. The counterforts may be designed 24" wide with a depth CD of 48". The wall between the counterforts will then have a clear span of 8 ft., but it will be on the side of safety and possibly better practice to calculate the bending moment for a span of 10 ft. or distance center to center of counterforts. The wall will be tapered from 10" at the bottom to 4" at the top determined by calculating loads per sq. ft. at the lower one foot section, center and upper sections. The counterforts may taper from 48" at CD to 12" at AB and will be reinforced with 5 rods, $1\frac{3}{4}$" diameter embedded in the concrete parallel to the inclined surface. To provide

for the longitudinal shear they should be deformed to effect a mechanical bond with the concrete and thoroughly anchored in the base. The reinforcement of the wall between the counterforts will consist of rods placed horizontally about 1½" inside of and parallel to the front face. These rods may all be ⅝" diameter and spaced 3" center to center at bottom and 9" centers at the top or larger rods may be used in the bottom and smaller ones on the top, so spaced as to give an equivalent area of metal. The shear between the intermediate sections of wall and the counterforts were investigated and amply provided for. In this design the heel projects 18" beyond the counterforts from **C** to H', the transverse rods in the top of the base may be omitted and longitudinal rods in the bottom of the heel substituted. 6 rods, 1¼" diameter will be sufficient. Longitudinal rods in the top of base will be required to resist the bending moment due to the upward reaction of the foundation between the counterforts. The weight of 10 lineal feet of the wall with counterforts will be ((1+ [illegible]) ÷ 2) x 2 x 19.[illegible] = [illegible]7.5 cu. ft., (0.33 + 0.83) ÷ 2 x 8 x 19.5 = 90.5 cu. ft.;

97.5 + 90.5 = 188 cu. ft., 188 x 140 = 26230#. The weight of the filling over the heel behind the wall will be (5.5 x 10 x 19.5) - 188 = 884.5 cu. ft.; 884.5 x 100 = 88450#. The weight of the base is 2 x 11 x 10 x 140 = 30800# and the total weight on the foundation will be 26230 + 88450 + 30800 = 145,480# or 14548# per lineal foot, 15050# in the previous example. The difference being less than 5% the resultant pressures on the foundations are satisfactory. Assuming that the reaction is transferred longitudinally to the counterforts by that part of the width of the base only which is under and covered by the counterforts and dividing 14548/48 the width of the portion assumed to carry load, we get 300# per lineal foot per inch width of beam. From table for a span of 10 feet we find a beam 20" deep is required, but our base is 24" deep, which gives a good margin of safety. The longitudinal reinforcement in the top of the base will then consist of 12 - 1¼" diameter round rods.

THE STORAGE SHED

In a plant having a capacity of from 60,000 to 80,000 brick per day, a storage place of large capacity is required. To this end, a building was designed to hold approximately two million brick, this affording ample room for storage of the finished product as well as the implements used in loading. To facilitate loading, the shed was designed as a long thin structure, located as near as feasible to the loading track. By virtue of the length of the building, it is possible to load five cars at once with a minimum of handling of the brick. The doors are made to swing outward, and are wide and high enough to permit the passage of a well loaded truck. The loading platform, being at the same level as the floor of the building and the cars, the loading of the material is greatly simplified.

The structure was designed for simplicity and as much beauty as was consistent with the purpose for which it was to be used. The panel effect is produced on the sides of the building

by the columns projecting from the wall a distance of three inches and on the end walls pilasters were used for stability as well as appearance. Standard material was used wherever possible and practically no special pieces were required. The roof consists of a slate covering laid on a steel truss. (The details of this truss are shown on plate 9).

The whole shed was designed to be thoroughly fire proof. The steel doors and window frames, and the concrete of the walls and foundation afford no fuel for a fire and the contents of the building are also incombustible. As this is an ideal case, the design may not be applicable to all conditions met with in actual construction. Considerable variation may be required where unusual conditions are met with, but under the average conditions this design will suffice. The exposed concrete surface is to be waterproofed with some good waterproofing material (ironite preferred) and treated with finishing tools where needed.

The walls were assumed to be six inches thick with 1/4 in. temperature rods extending thru the

center. Inasmuch as the weight of the roof is carried at the panel points, this thickness was adopted and found to be as heavy as needed in a building of this sort. Where doors and windows were to be put in, I beam reinforcing was used to carry the load of the material above the openings. The following calculations show the method of deciding upon the reinforcing needed.

Assuming a door 8'-0" wide and 7'-0" high, the weight of the concrete above the door would be $\frac{8X5}{2}$ X 150 = 3000#. Using the Cambria steel book, on page 85 we find tables for the proper design, and on page 82, a description of the use of these tables. Assuming a span of 11'-0", we find the safe load above to be 5160#. Applying the formula, we have 5160 X 100/121 = 4260# as the safe load for a 5" I beam - 9.75# 1 ft. As this is in excess of the load to be applied, this beam is adaptable to our design.

Assuming a 9 ft. span over the windows, we have a load of $\frac{7.3 X 4}{2}$ x 150= 2190# to be supported.

Using a 7.5# - 4# in. I beam, the safe load is $\frac{3980 \times 64}{81} = 3140\#$. As the next smaller beam has a safe load less than the load to be upheld, the 7.5# - 4 in. beam was used. This size beam was found to be adaptable for use in the end windows as well as the side windows.

The doors are steel and are hung on standard hinges and need no further remarks except to mention that the width of 8'-0" and height of 7'-0" allows a fully loaded truck to pass them.

The windows were designed to give a maximum amount of lighting area without the use of skylights. To this end, standard Fenestra steel windows (#Y 73) 7'-3 1/2"X 4'-8" were used in the side walls. This size is as large as feasible and danger of breakage is lessened by division of the lighting space into twenty-one small panes. In the end walls, 7'-3 1/2" X (Y36) 7'-8 3/4" - 35 pane windows were used at each side and a 9'-3 1/8" X 6' - 4 3/16" (Y36) - 36 pane was used in the center, as, shown on the drawing. The method of making the connection of the windows

to the wall is standard for Fenestra steel windows and is shown in detail in the drawing. These large windows in the ends of the building and the smaller over along the sides, together with the openings formed by the doors should give enough light for the handling of material. The steel window frames insure a perfect fire-proof structure throughout as well as maximum stability of the structure.

The columns were designed to be one foot square and twelve feet above the ground line, making a total height of fourteen feet from the top of the footing to the top of the walls. The load to be carried at the panel points is 13,650# (the weight of the roof - allowance being made for wind pressure.) Assuming a working value of 400# 1 sq. in. for plain concrete, a plain column would have a safe strength of 144 X 400 =57,600#. As the load to be carried was about one fourth of this, there was no reinforcing actually required. To make the corners of the column strong, 7/8 in. round twisted rods were placed in each corner. This gave assurance of very little danger of the

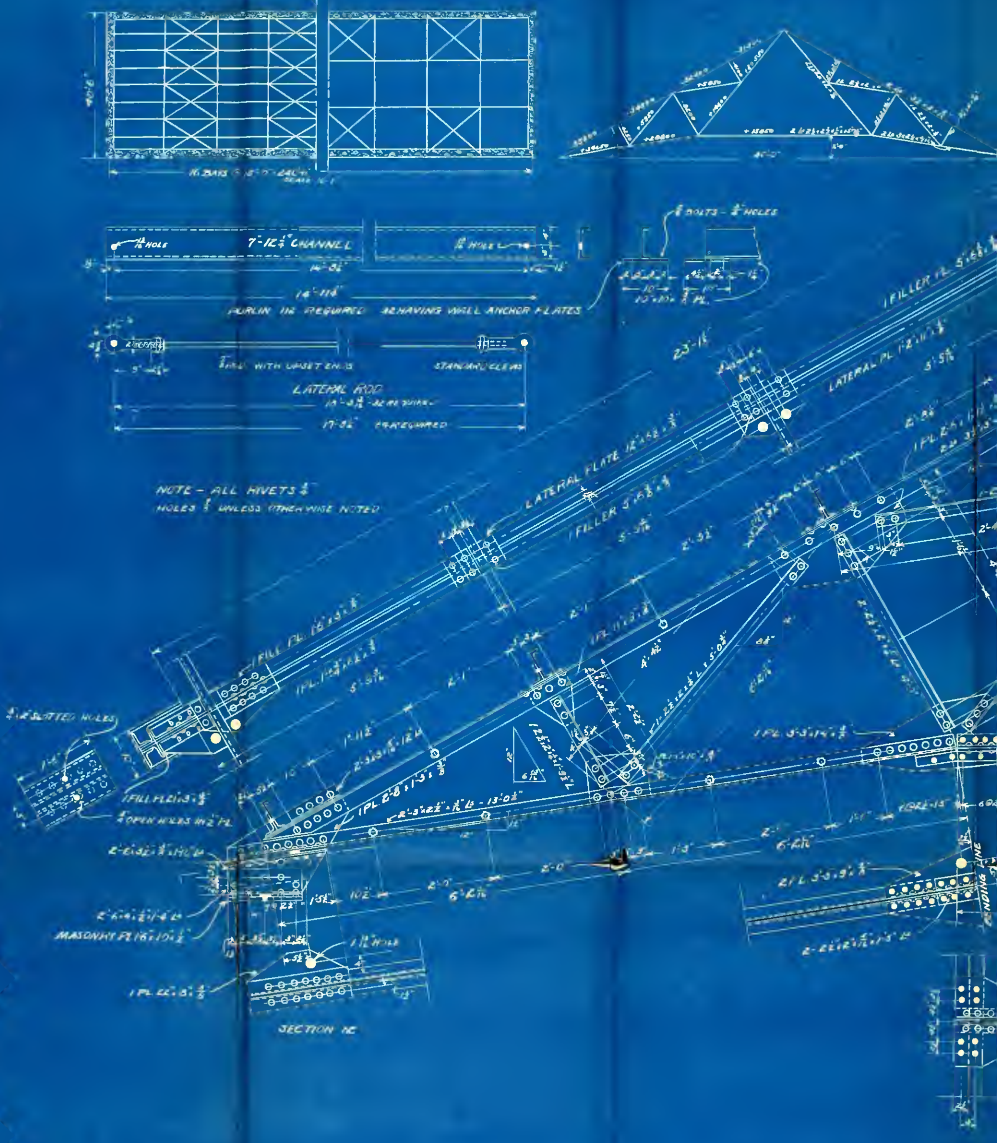
corners breaking.

The footings at each column were designed on the assumption that the ground underneath would uphold a pressure of 3,000# per sq. ft. The load to be applied consisted of 13,650#.

13650/3000 equals 4.55 sq. ft. needed. Assuming a footing 2'-3" square, we have an area of 5.07 sq. ft. to bear the load, which is large enough to carry the load from the roof as well as the weight of the column. Between columns, the footing was assumed to be 1'-0" wide. As the weight of the concrete was the only load to be carried, the actual area required was $\frac{9300}{3000}$ =3.1 sq. ft. The area affected by this one foot footing was 12.7 sq. ft. The footings were carried to a depth of 2'-0" all around the building. This involves a total depth of 4'-0" below the ground line, which is ample for stability. This design was ample for the actual needs and sufficient stability.

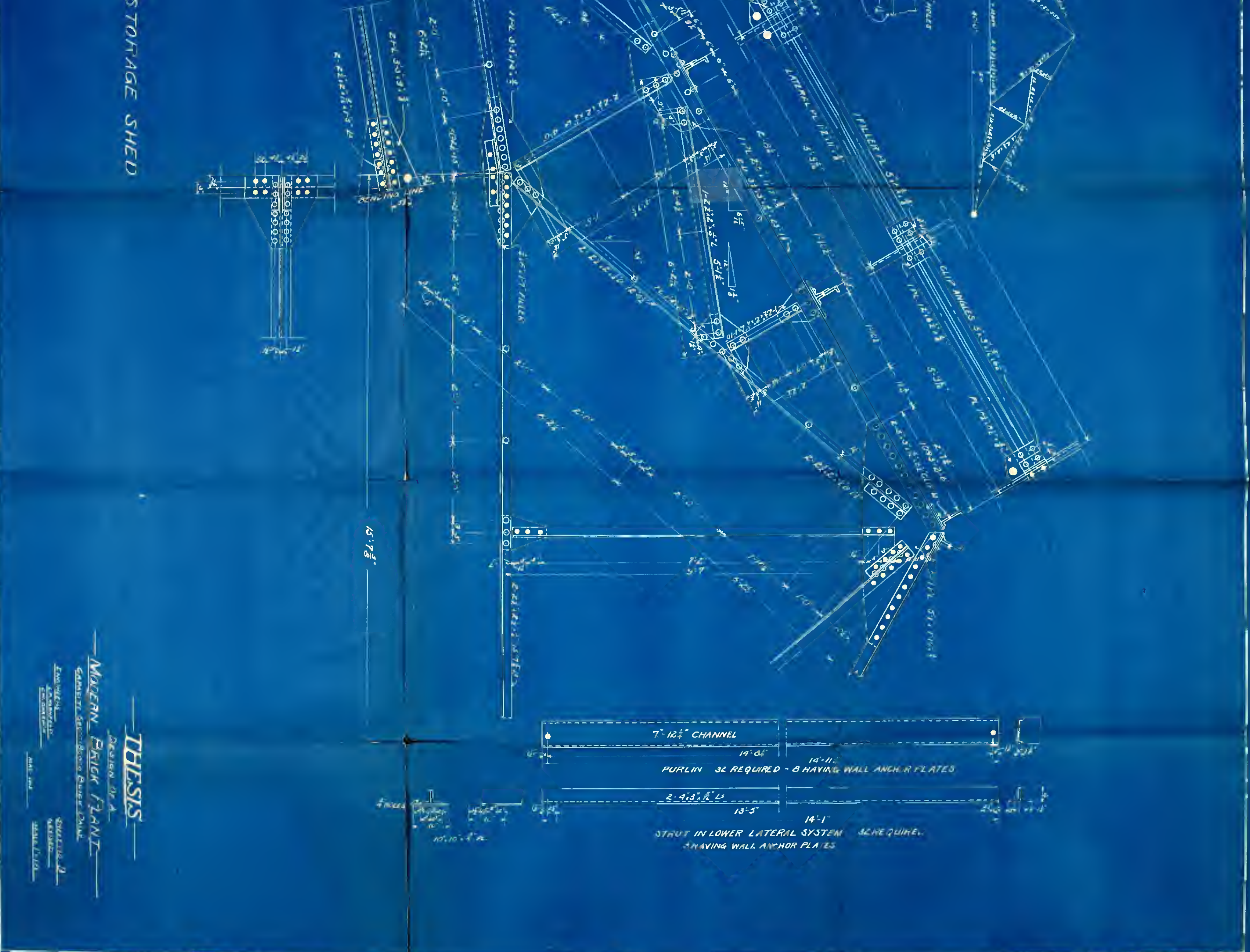
Inasmuch as the material to be stored was not excessively heavy, a very simple floor construction was decided upon. A bed of cinders is laid down to a

depth necessary to have the cinders in contact with firm soil. These cinders are tamped thoroughly and rolled very carefully and brought to the required level. After the cinder bed has been compressed into a compact mass, a 4 in. layer of 1-3-6 concrete is laid on top of it. A layer 2 in of 1-2-3 concrete is then put down to form a trucking surface. This design is simple and inexpensive and affords a good solid floor for the storage of the brick. Cross walls are to be used where the ground is not firm enough to permit construction of this sort.



NOTE - ALL RIVETS ¾"
HOLES ⅞" UNLESS OTHERWISE NOTED

DETAILS OF ROOF TRUSS FOR STORAGE SHED

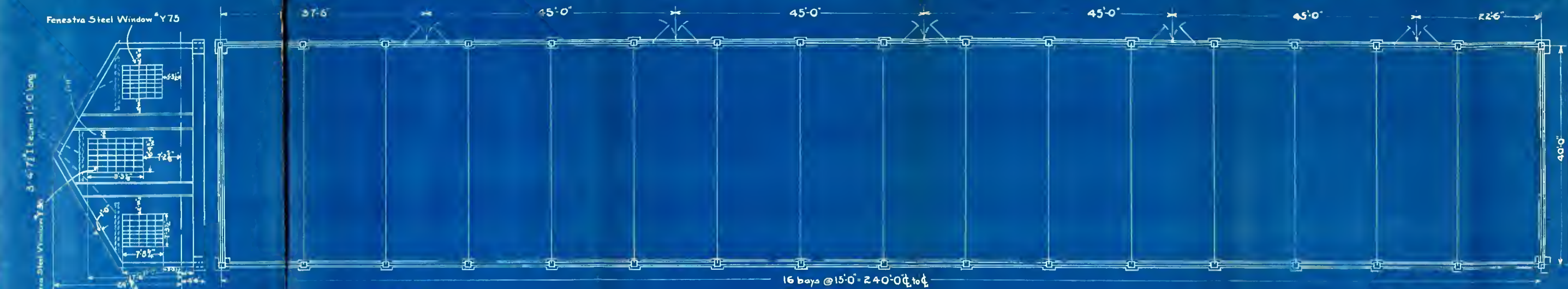


THESIS

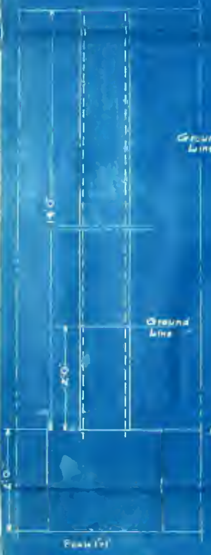
Design of a

Modern Brick Plant

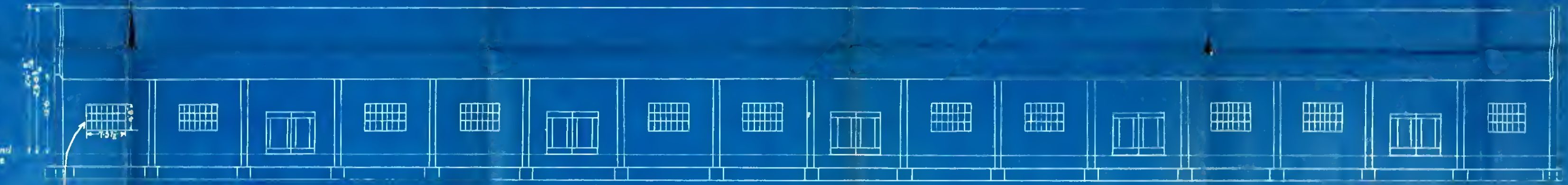
Capacity 30,000 Brick Daily


Fenestra Steel Window #Y75
3'-4" 7½" I beams 1'-0" long
Fenestra Steel Window #Y36
7'-2¾"
9'-3⅝"
7'-8¾"
37'-6"
45'-0"
45'-0"
45'-0"
45'-0"
22'-6"
40'-0"
16 bays @ 15'-0" = 240'-0" ℄ to ℄

Scale 1" = 8'



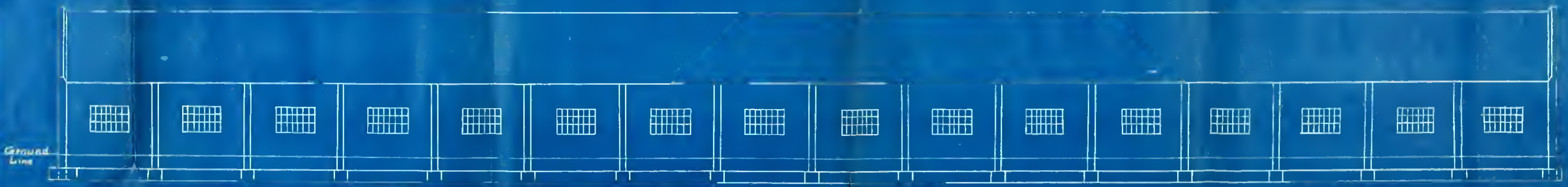
Scale 1" = 1'



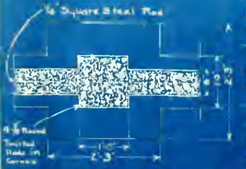
Fenestra Steel Window #Y73

Scale 1" = 8'

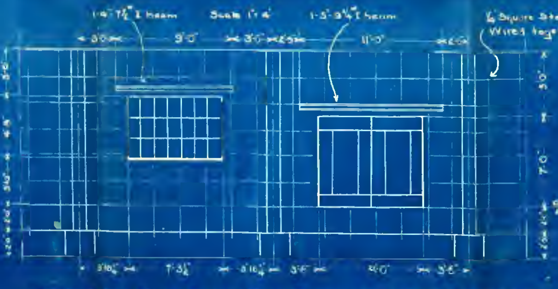
North Elevation of Storage Shed.



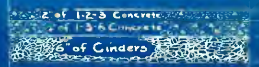
South Elevation.



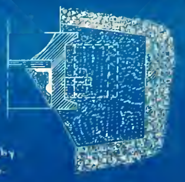
Section of Wall Showing Details of Wall, Pillar and the Foundations.



Section of Wall Showing Door and Window Dimensions and Method of Reinforcing



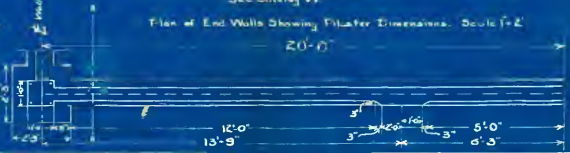
Section thru Floor.

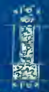


Section showing method of connecting windows to wall.

Steel Windows designed by Detroit Steel Products Co. See Catalog W.

Plan of End Walls Showing Pilaster Dimensions. Scale 1" = 2'





Section at A-A

THESIS

DESIGN OF A

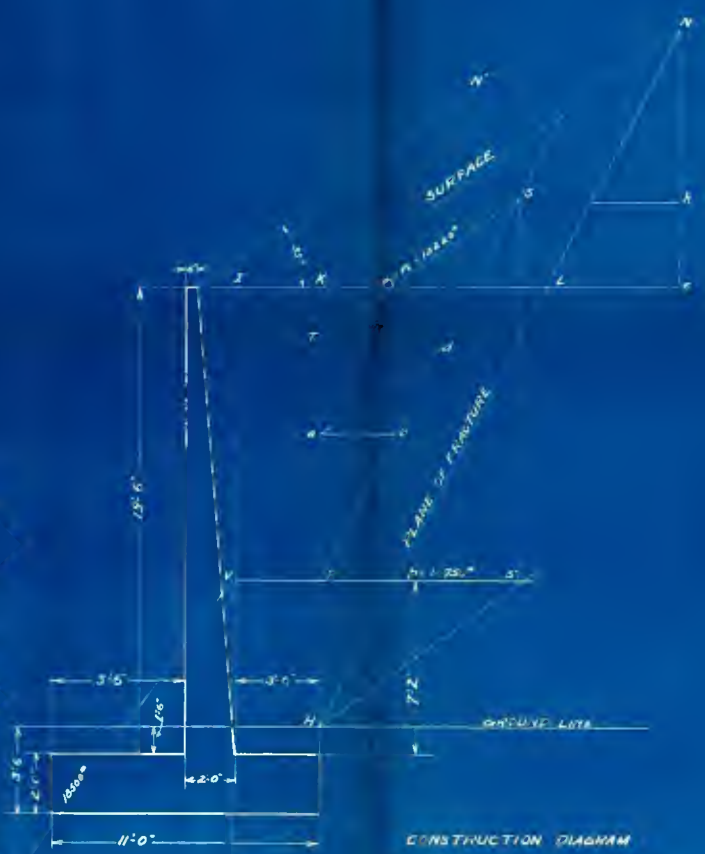
MODERN BRICK PLANT

CAPACITY [illegible] BRICK DAILY

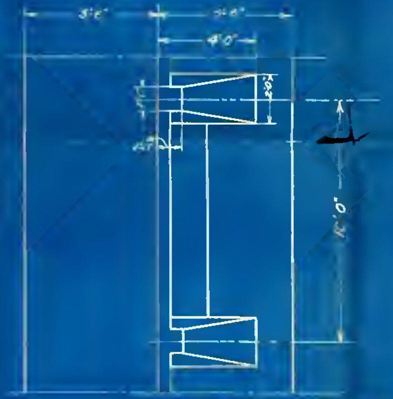
Engineers:
[illegible]
[illegible]

MAY 1913

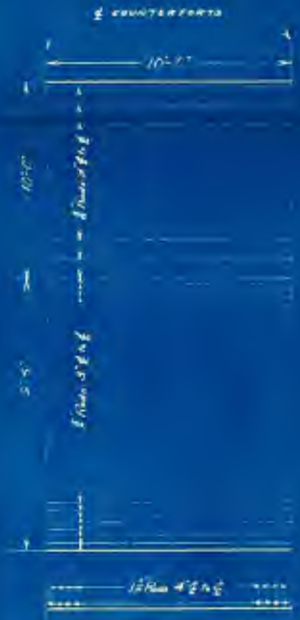
Sheet No. 8
Revised:
[illegible]



CONSTRUCTION DIAGRAM



LOOKING DOWN ON THE WALL
NOTE COUNTERFORT CONSTRUCTION



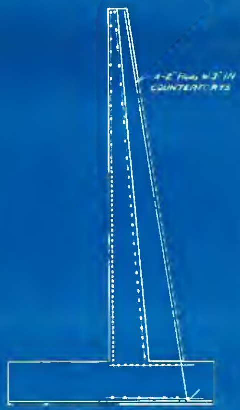
PLAN OF RODS IN BACK OF WALL

RETAINING WALL FOR STORAGE BIN

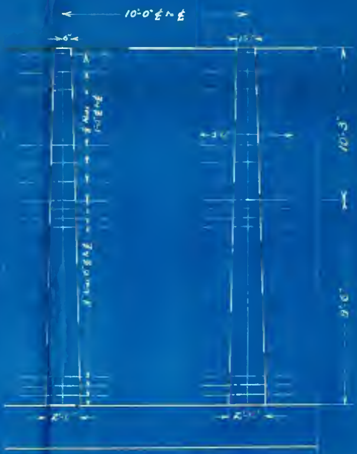
SCALES 1"-3'-4000#

IN BACK OF WALL

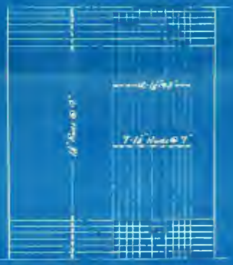
AGE BIN



SECTION AT COUNTERFORT



PLAN OF RODS IN FACE OF WALL



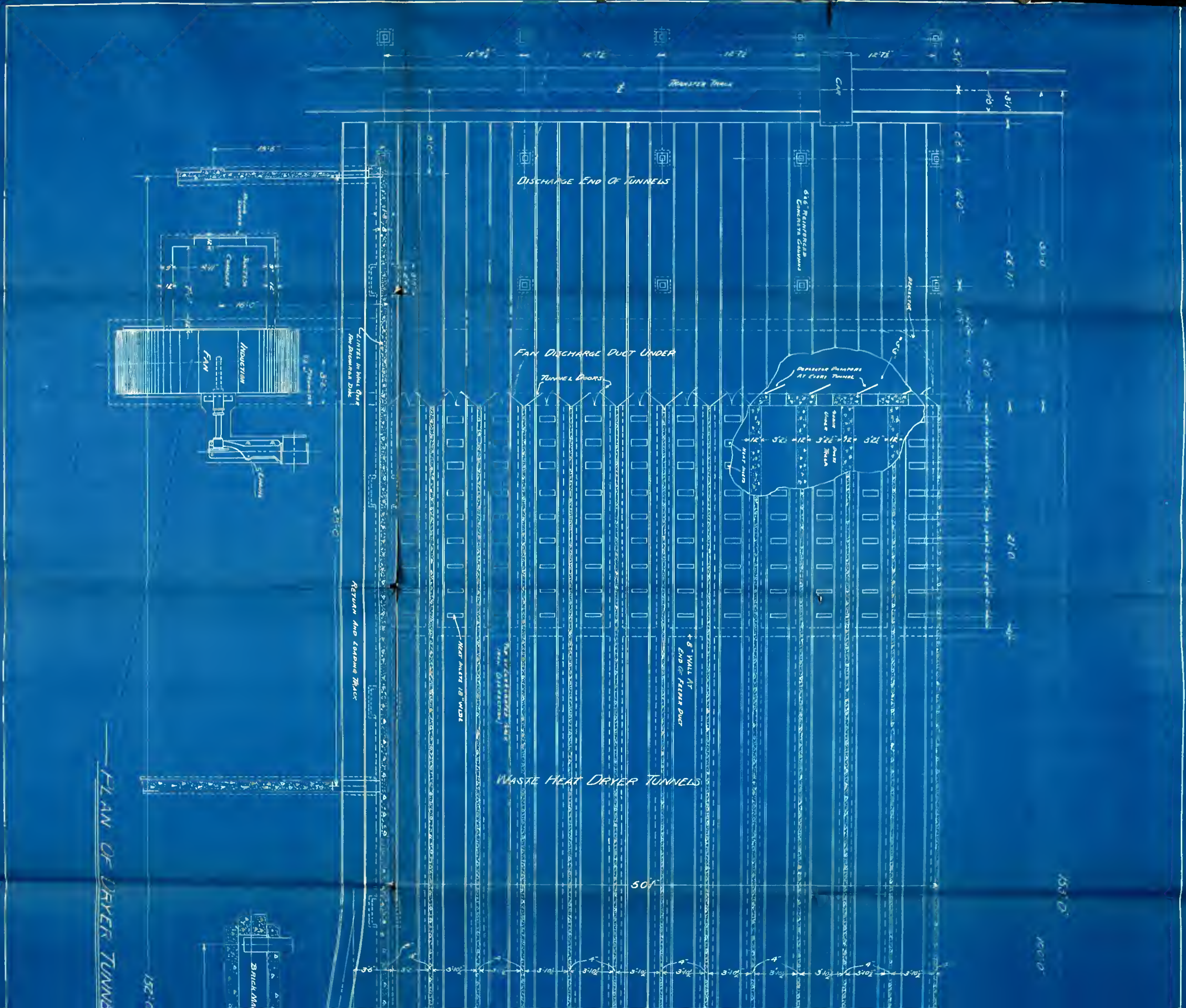
PLAN OF RODS IN FOOTING

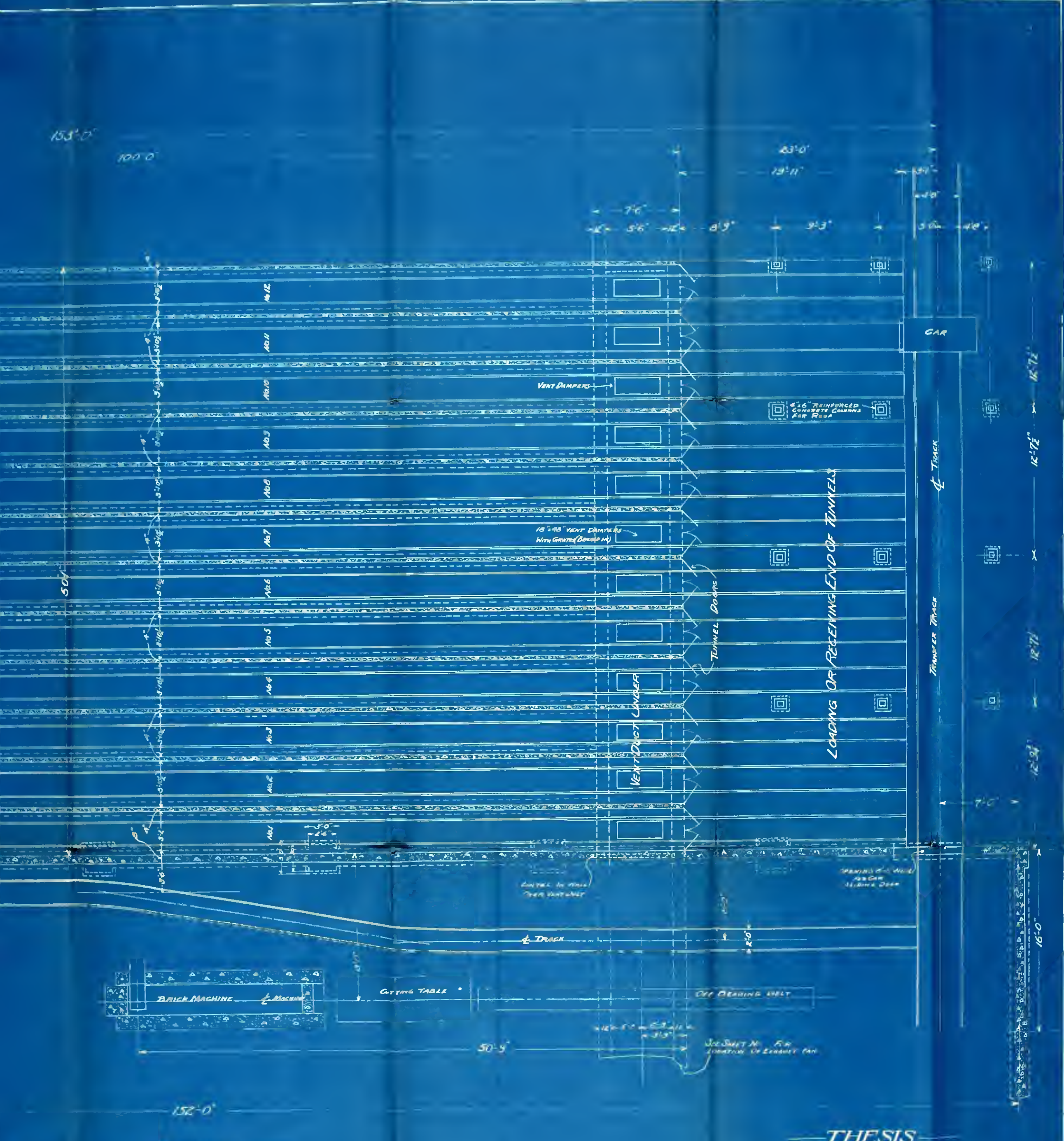
THESIS
Design of a
Modern Brick Plant
Capacity [illegible] Brick Daily

Engineers
[illegible]
[illegible]

Sheet No 7
Revised

May-1913


PLAN OF DRYER TUNN
12'7½"
12'7½"
12'7½"
12'7½"
℄
TRANSFER TRACK
CAR
DISCHARGE END OF TUNNELS
6'6" REINFORCED CONCRETE COLUMNS
REFLECTOR
FAN DISCHARGE DUCT UNDER
TUNNEL DOORS
DEFLECTOR DAMPERS AT EVERY TUNNEL
12"
3'2½"
12"
3'2½"
12"
3'2½"
12"
HEAT INLETS
HEAT INLETS 18" WIDE
8" WALL AT END OF FEEDER DUCT
18'8"
SUCTION CHAMBER
16'0"
12"
9"
INDUCTION FAN
LINTEL IN WALL OVER FAN DISCHARGE DUCT
RETURN AND LOADING TRACK
WASTE HEAT DRYER TUNNELS
50'1"
3'6"
3'10½"
4"
BRICK
26'11"
33'0"
21'0"
153'0"
160'0"
132'0



N OF DRYER TUNNELS

THESIS

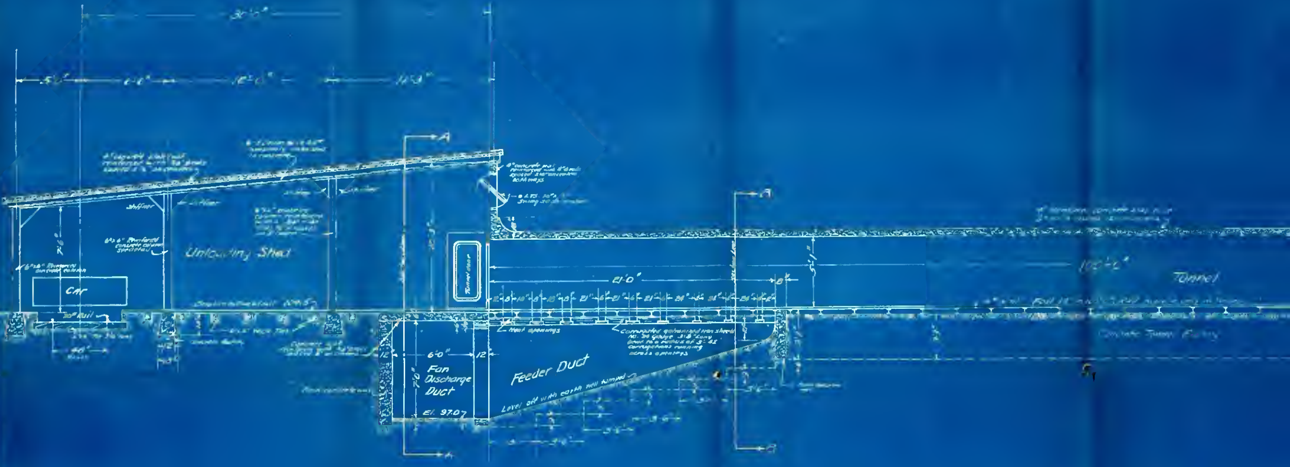
DESIGN OF A

MODERN BRICK PLANT

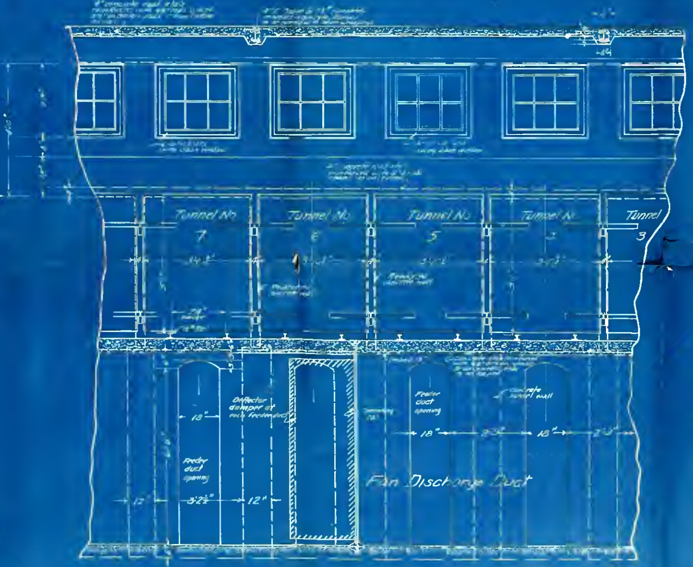
CAPACITY [illegible] BURNED BRICK DAILY

ENGINEERS:
[illegible]
[illegible]

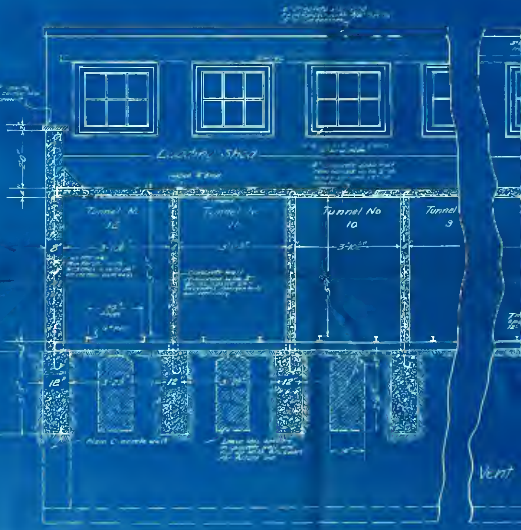
SHEET NO. 6
REVISED:
SCALE: [illegible]



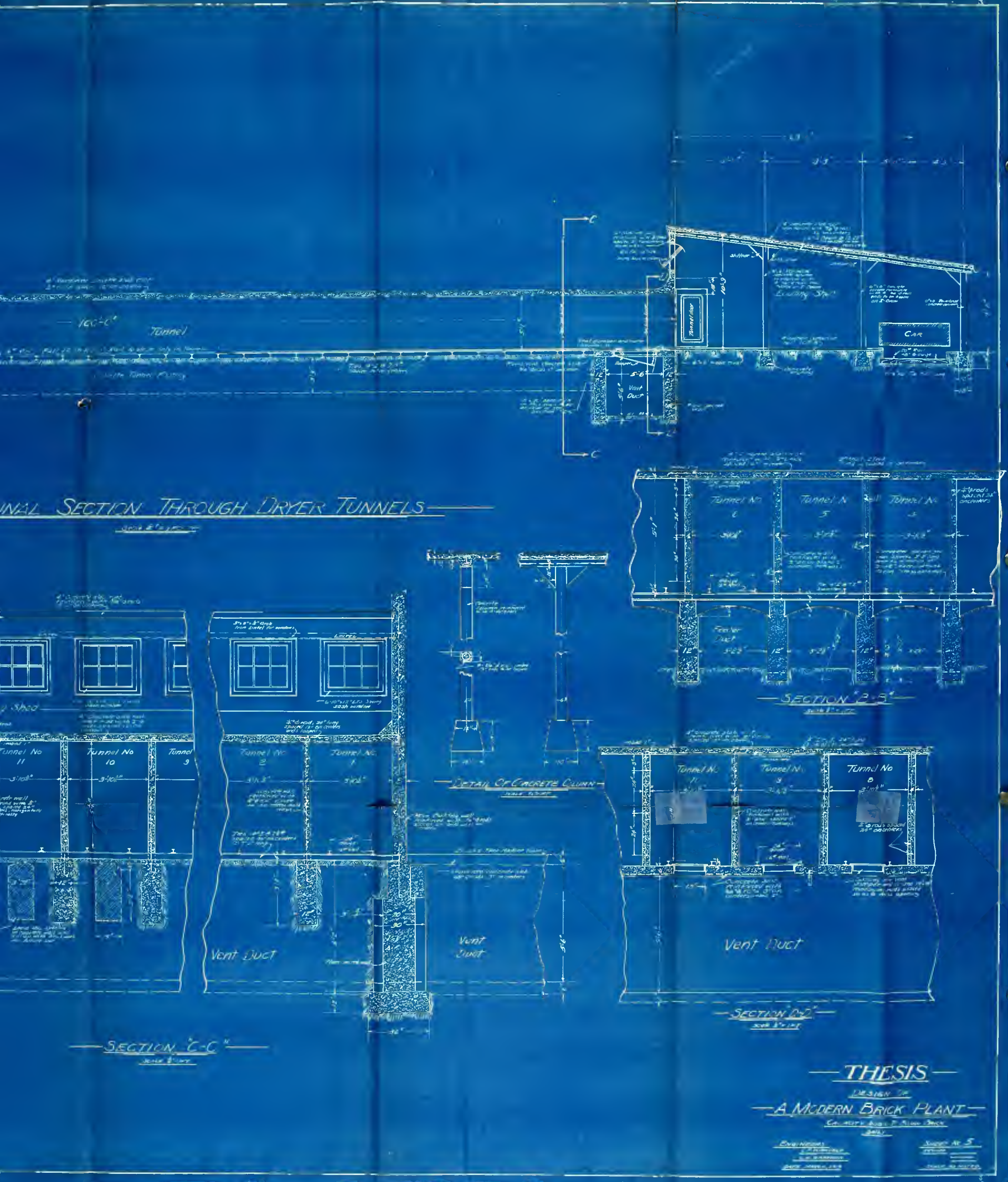
LONGITUDINAL SECTION THROUGH



SECTION "A-A"



SECTION "C-C"

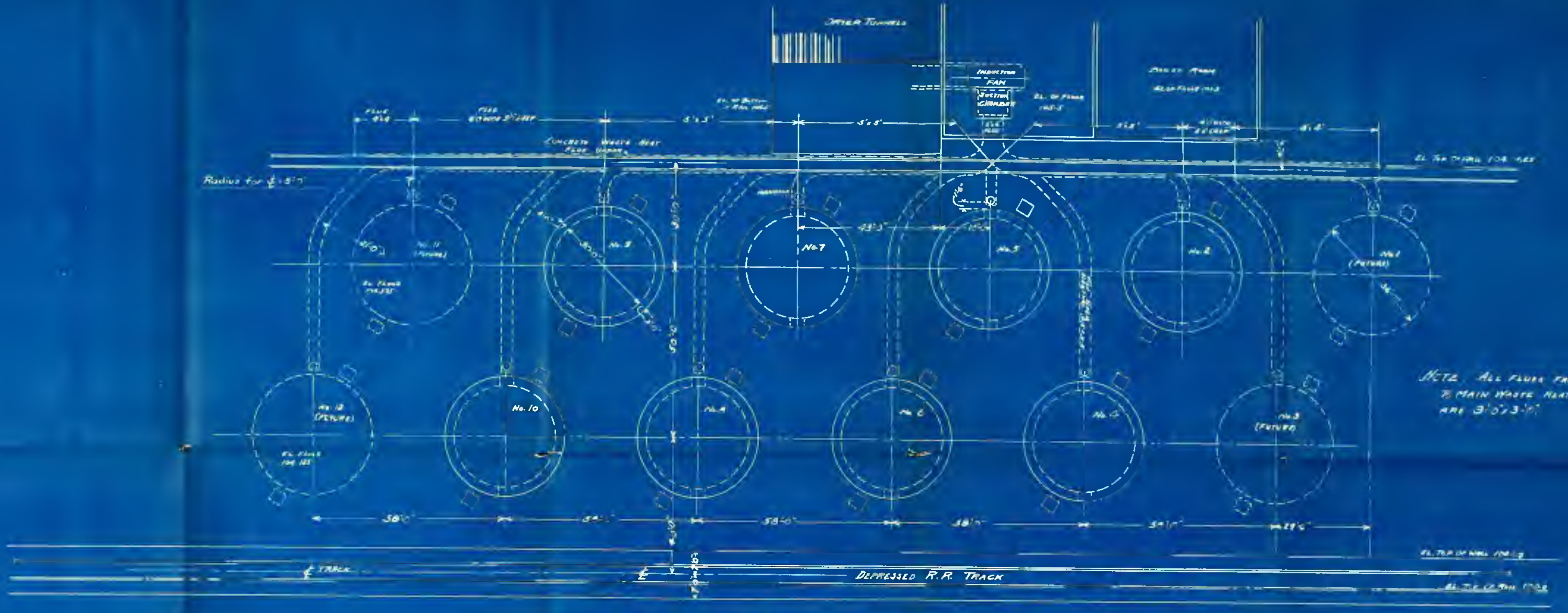


THESIS

DESIGN OF

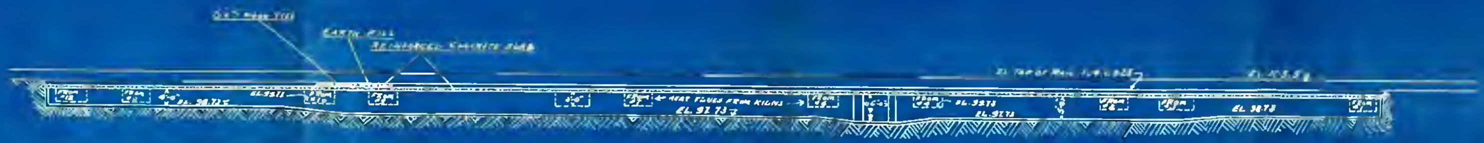
A MODERN BRICK PLANT

Sheet No 5

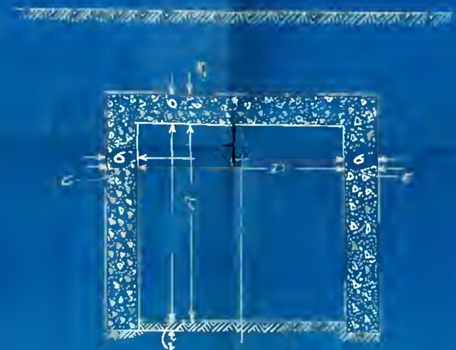


NOTE. All flues from kilns to main waste heat flue are 3'-0" x 3'-0".

PLAN OF KILNS SHOWING WASTE HEAT FLUES

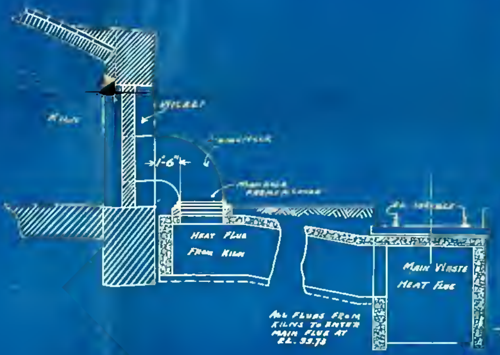


LONGITUDINAL SECTION THRU MAIN WASTE HEAT FLUE



CROSS SECTION OF WASTE HEAT FLUE

SIZE FLUE	A	B	C	D	E	ELEVATION AT BOTTOM	REINFORCING
6'x6'	6'	6"	1'	6'	1'	96.73	½" Round Rods @ 4"
5'x5'	6'	6"	1'	5'	1'	97.73	" " " " "
4'x5'	5'	6"	1'	4'	1'	97.73	" " " @ 5"
4'x4'	4'	6"	1'	4'	1'	98.73	" " " " "
3'x3'	3'	4"	6"	3'	6"	99.73 AT MAIN FLUE WALL	" " " @ 6"

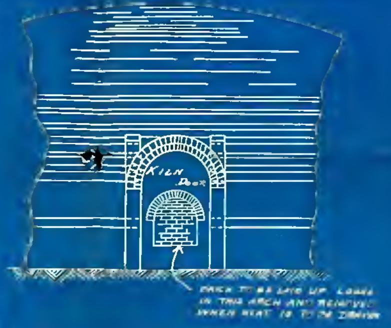


All flues from kilns to enter main flue at El. 99.73

CROSS SECTION THRU KILN DOOR

SHOWING GOOSENECK

No Scale



Brick to be laid up loose in this arch and removed when heat is to be drawn

FRONT ELEVATION OF KILN DOOR

SHOWING ARCH IN WICKET FOR GOOSENECK

THESIS

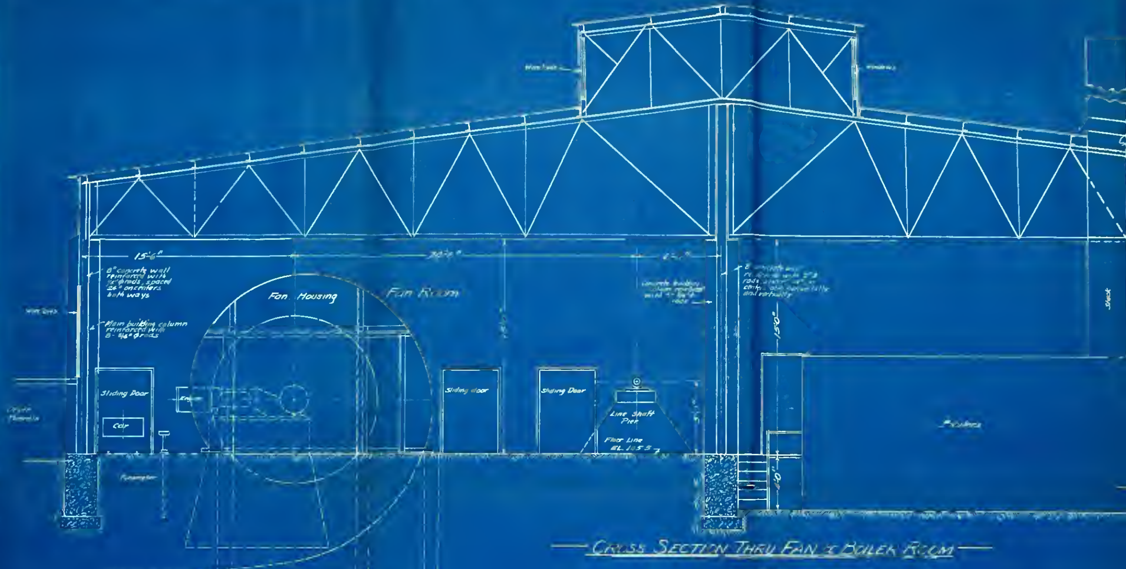
DESIGN OF A

MODERN BRICK PLANT

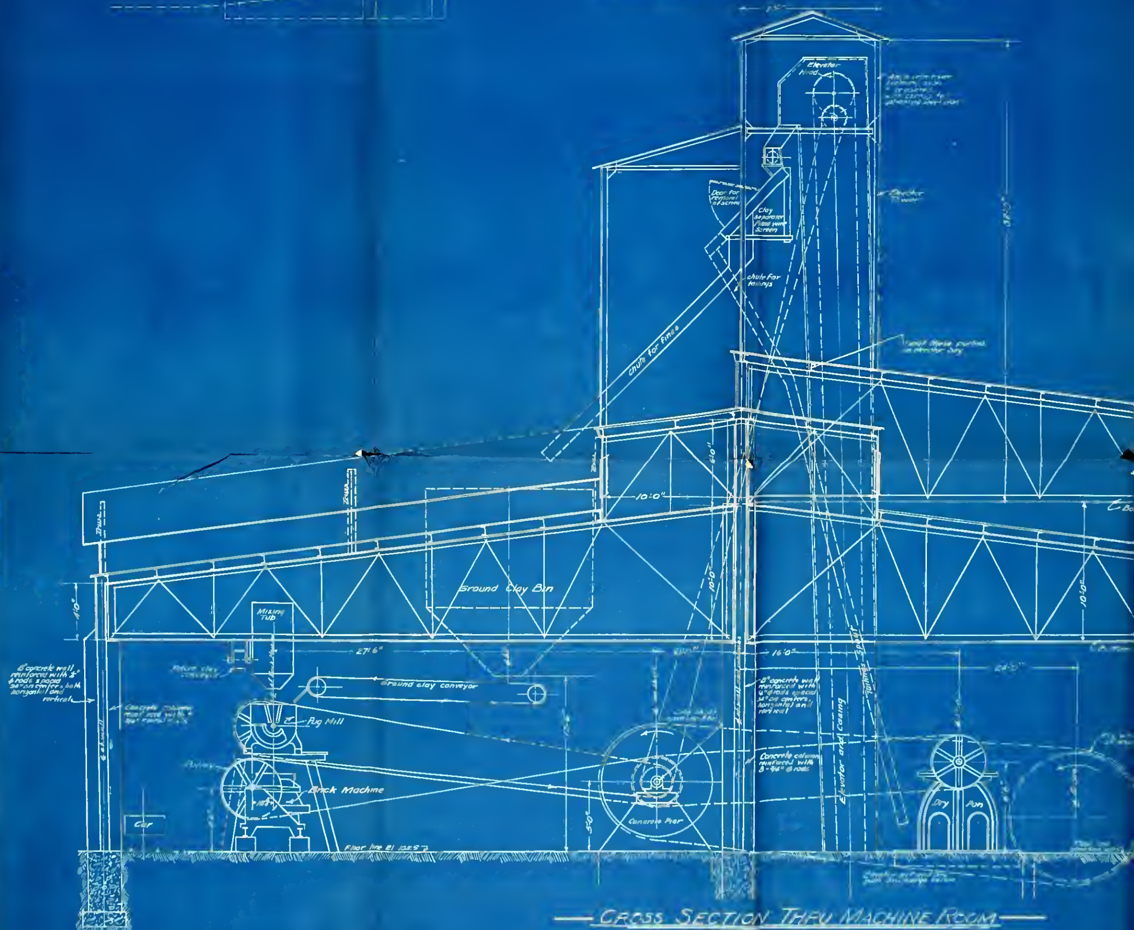
Capacity [illegible] Brick per day

Sheet No. 3

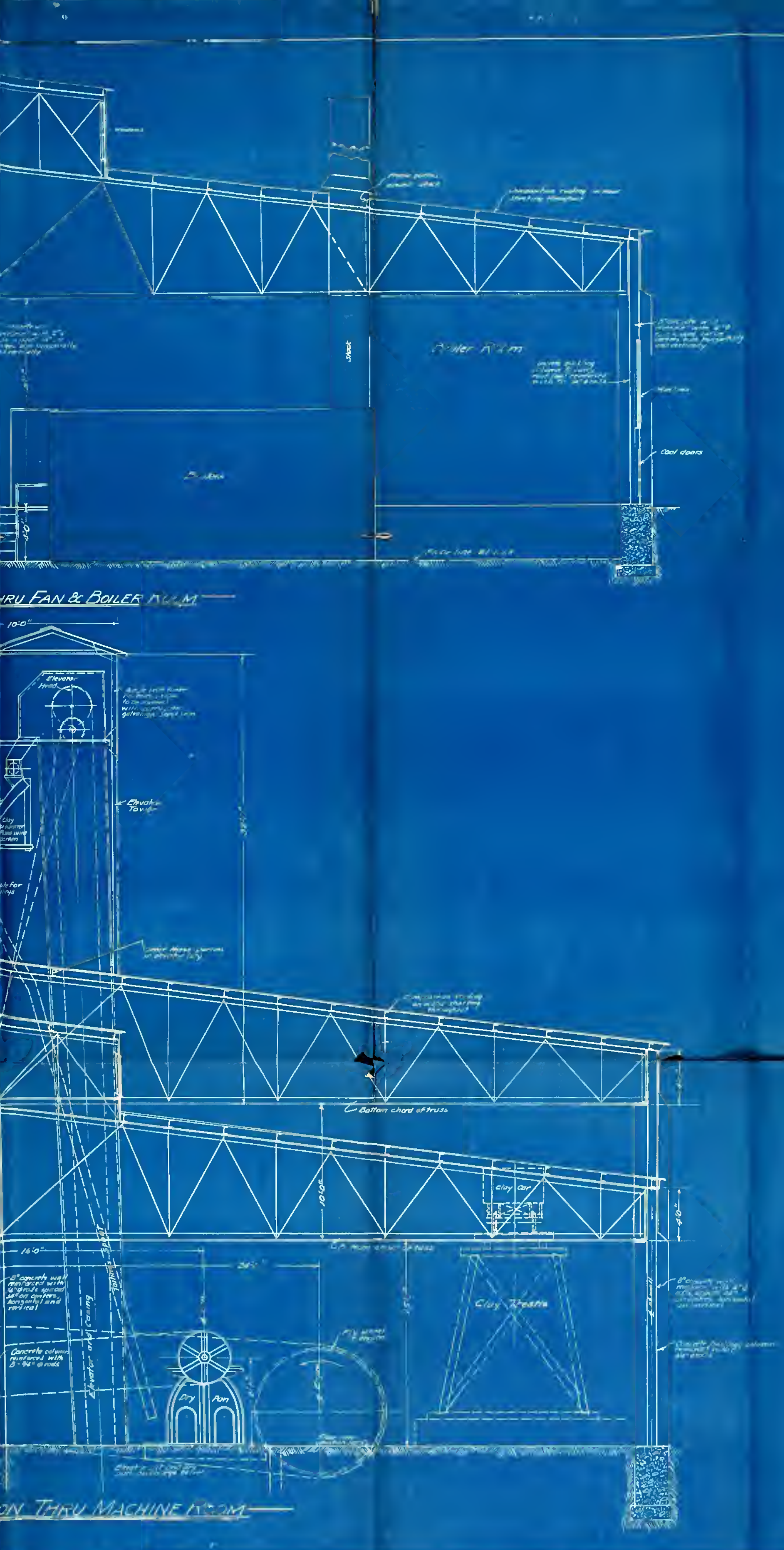
Scales as noted


15'-6"
8" concrete wall reinforced with ½" ⌀ rods, spaced 24" on centers both ways
Main building column reinforced with 8 - ¾" ⌀ rods
Fan Housing
Fan Room
Sliding Door
Car
Engine
Sliding door
Sliding Door
Line Shaft Pier
Floor Line EL. 105.5
15'-0"
4'-0"
Stack

CROSS SECTION THRU FAN & BOILER ROOM


Elevator Head
Door for removal of screen
Clay Separator Piano wire Screen
chute for tailings
chute for fines
Ground Clay Bin
10'-0"
6'-0"
4'-0"
Mixing Tub
27'-6"
Ground clay conveyor
Pug Mill
Brick Machine
Car
Floor line El. 105.5
8" concrete wall reinforced with ½" ⌀ rods spaced 24" on centers, both horizontal and vertical
16'-0"
8" concrete wall reinforced with ½" ⌀ rods spaced 24" on centers, horizontal and vertical
Concrete column reinforced with 8 - ¾" ⌀ rods
Elevator and Casing
Tailings Spout
Concrete Pier
5'-0"
Dry Pan
24'-0"

CROSS SECTION THRU MACHINE ROOM



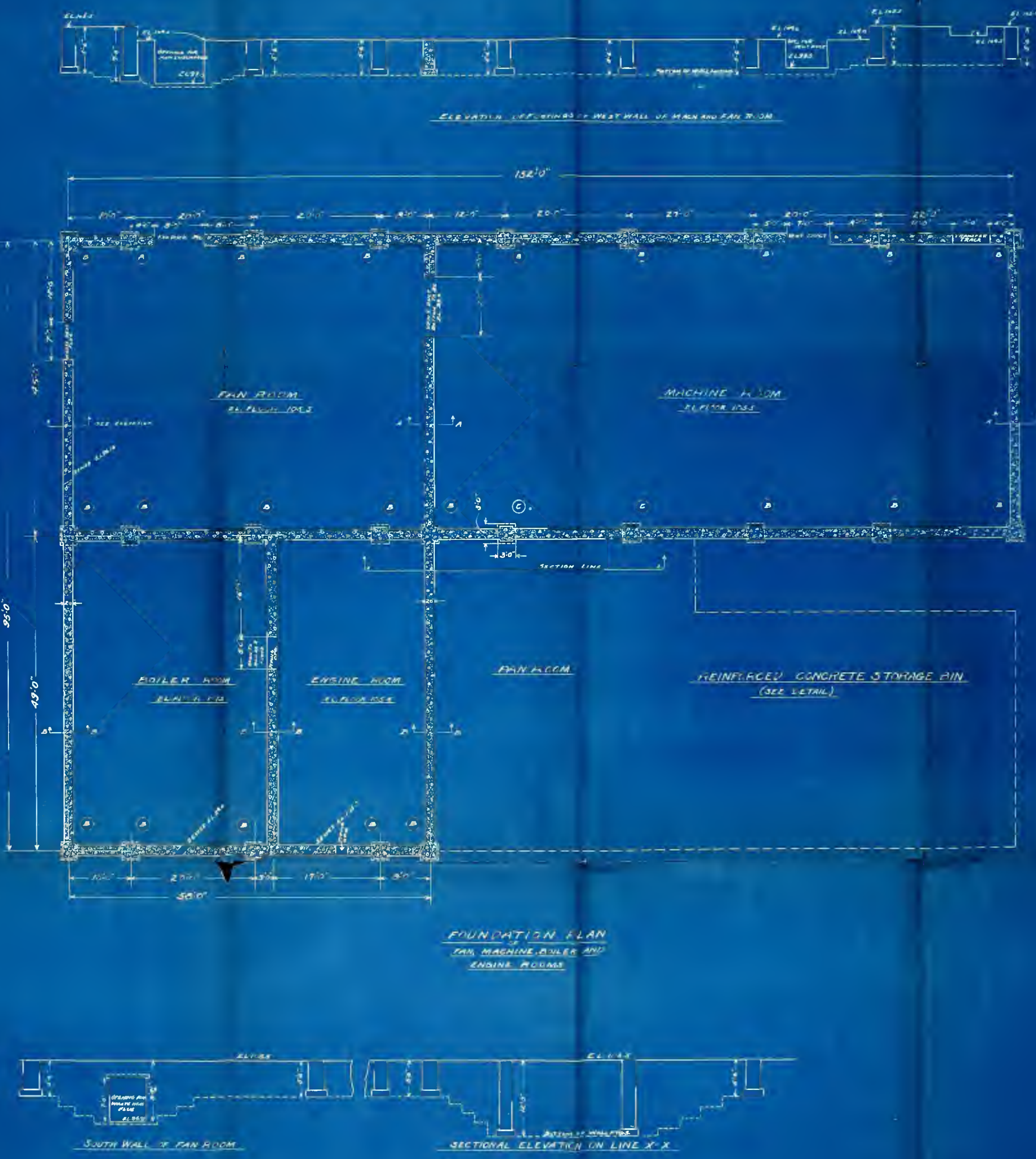
/ —THESIS—

DESIGN OF

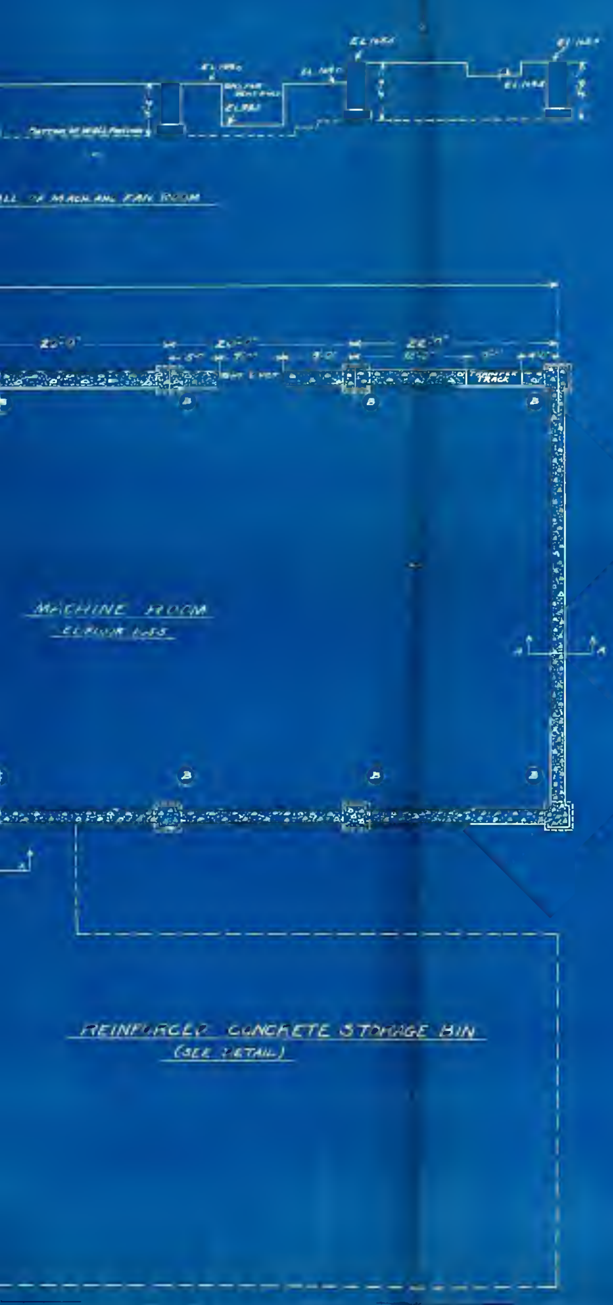
—A MODERN BRICK PLANT—

CAPACITY 40000 TO 60000 DAILY

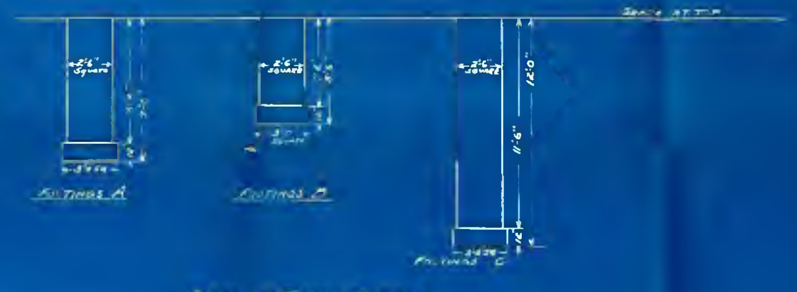
SHEET NO. 3



FOUNDATION PLAN
OF
FAN, MACHINE, BOILER AND
ENGINE ROOMS

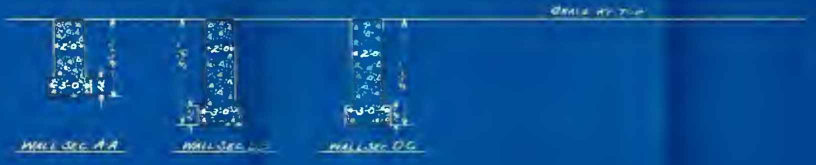


NOTE! ELEVATION OF TOP OF CONCRETE FOUNDATIONS
TO BE 115.5 EXCEPT AS NOTED.
DEPTH OF ALL COLUMN AND WALL FOOTINGS
TO BE MEASURED FROM ITS RESPECTIVE
TOP ELEVATION.



DETAIL OF COLUMN FOOTINGS

LETTERS NEAR COLUMNS AND SECTION LINES INDICATE TYPE OF CONSTRUCTION
COLUMNS AND FOOTINGS ARE MADE OF REINFORCED CONCRETE



DETAILS OF WALL FOOTINGS

TABLE OF GRADES

FLOOR MACHINE ROOM	116.5
" BOILER "	101.5
" ENGINE "	115.5
" FAN	115.5
TOP OF RAIL OF [illegible] TRACK	[illegible]
TOP OF RETAINING WALL	[illegible]

THESIS

DESIGN OF A

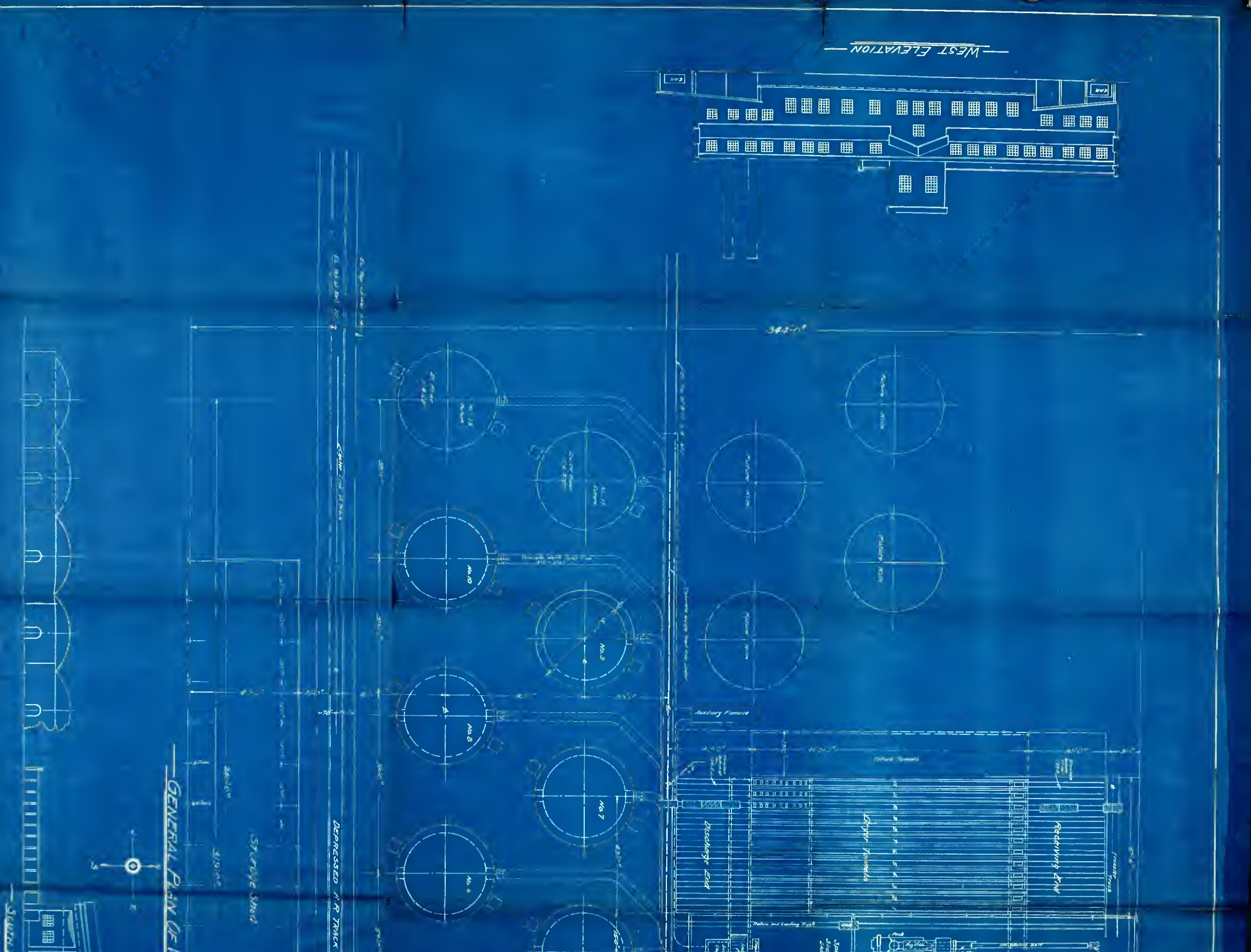
MODERN BRICK PLANT

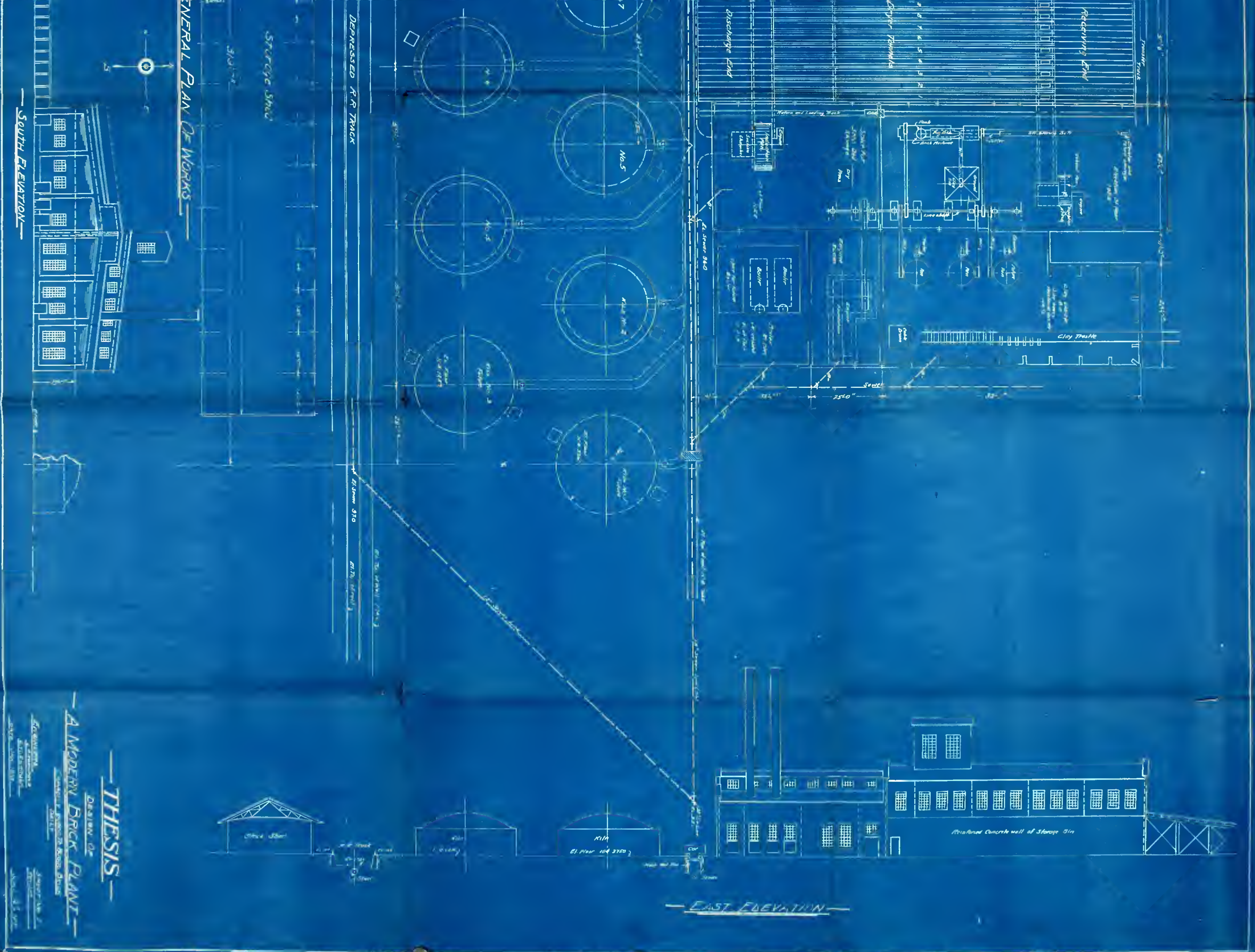
CAPACITY [illegible] BRICK DAILY

ENGINEERS
[illegible]
[illegible]

MAY 1913

SHEET No. 2
[illegible]
SCALE [illegible]


WEST ELEVATION
CAR
344'-0"
No. 10
No. 9
No. 8
No. 7
No. 6
Future Kiln
Auxiliary Furnace
Future Tunnels
Discharge End
Dryer Tunnels
Receiving End
Transfer Track
Platform and Loading Dock
Storage Shed
DEPRESSED R R TRACK
GENERAL PLAN OF


THESIS
DESIGN OF
A MODERN BRICK PLANT
GENERAL PLAN OF WORKS
SOUTH ELEVATION
EAST ELEVATION
DEPRESSED R.R. TRACK
STORAGE SPACE
Discharge End
Dryer Tunnels
Receiving End
Transfer Track
No. 5
Boiler
Boiler
Clay Trestle
Sewer
25'0"
Kiln
El. Floor 104.3750
Office Shed
Car
Reinforced Concrete wall of Storage Bin